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Sewage Works Journal

Published by

Federation of Sewage Works Associations

Easton, Pa.

Vol. IV **March, 1932** **No. 2**

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Federation Affairs

Minutes of the Annual Meeting of the Board of Control Federation of Sewage Works Associations

The annual meeting of the Board of Control of the Federation of Sewage Works Associations was held in the office of the Chemical Foundation, Incorporated, 654 Madison Avenue, New York City, on Friday afternoon, January 22, 1932.

The following were present:

Name	*Representing*
William W. Buffum, New York City	Bus. Mgr.—Member-at-Large
J. W. Bugbee, Providence, R. I.	New England S. W. Assn.
J. R. Downes, Bound Brook, N. J.	Member-at-Large
C. A. Emerson, Jr., Philadelphia, Pa.	Chairman, Penna. S. W. Assn.
L. M. Fisher, New York City	Federal Sew. Research Assn.
Charles G. Hyde, Berkeley, Cal.	California S. W. Assn.
F. G. Merckel (for W. J. Orchard), Newark, N. J.	Member-at-Large
H. E. Moses, Harrisburg, Pa.	Secy.-Treas., Penna. S. W. Assn.
Earle B. Phelps, New York City	New York State S. W. Assn.
Dr. Willem Rudolfs, New Brunswick, N. J.	New Jersey S. Conf.
John F. Skinner, Rochester, N. Y.	New York State S. W. Assn.
By Proxy:	
C. K. Bullen, Stillwater, Oklahoma	Oklahoma W. & S. Conf.
H. J. Darcey, Oklahoma City, Okla.	Oklahoma W. & S. Conf.
F. H. Dryden, Salisbury, Md.	Md.-Del. W. & S. Assn.
V. M. Ehlers, Austin, Texas	Sew. Div. Texas Sect.—S.W.W.A.
R. E. Fuhrman, Springfield, Mo.	Missouri W. & S. Conf.
W. S. Mahlie, Fort Worth, Texas	Sew. Div. Texas Sect.—S.W.W.A.
J. H. Rider, Tucson, Ariz.	Arizona S. W. Assn.
J. R. Rumsey, Grand Rapids, Mich.	Michigan S. W. Assn.
R. C. Smith, Glen Ridge, N. J.	New Jersey S. Conf.
H. W. Streeter, Cincinnati, Ohio	Member-at-Large
R. E. Tarbett, Washington, D. C.	Federal Sew. Research Assn.
L. F. Warrick, Madison, Wis.	Central States S. W. Assn.
Abel Wolman, Baltimore, Md.	Vice Chairman, Md.-Del. W. & S. Assn.

The Chairman, C. A. Emerson, Jr., presided.

The minutes of the annual meeting held January 22, 1931, were read and upon motion duly made and seconded, were approved.

The report of the Secretary-Treasurer was read, and upon motion, accepted and approved. This report indicated that there were fifteen (15) groups making up the Federation, having an aggregate membership of 1325, a gain during the year of 82.

The Business Manager made his report, which, upon motion, was accepted and approved. This showed the Federation to be in good financial condition with a balance on hand December 31, 1931, of $2063.29. A commentary on the excellent management of Mr. Buffum was indicated by the fact that in spite of the depression the SEWAGE WORKS JOURNAL showed a net profit of $56.97.

Under the heading of Reports of Standing Committees, Chairman Emerson verbally made an abstract of a report by Chairman Streeter of the Membership Committee. Upon motion, seconded and carried, this report was received.

Pursuant to authorization given the Chairman at the 1931 annual meeting of the Board, he appointed a Special Committee on Standardization of Methods of Sewage Analysis with E. J. Theriault as Chairman. Mr. Emerson stated that he had a letter from Mr. Theriault informing him that this Committee had organized during the past year and had considered and laid out plans for its work and was now getting well started in the carrying out of these plans. It was the opinion of the Board that the work should be continued, and upon motion duly made, seconded and carried, the recommendations of the Committee for carrying out its work were adopted, and the Committee was continued.

Discussion next ensued concerning the affiliation of associations in other countries with the Federation. Chairman Emerson explained briefly that the matter was discussed in the 1930 Annual Meeting of the Federation and that subsequently considerable correspondence has been had with various groups abroad, and suggestions have been made to those interested that if a group were formed of persons interested in the aims and objects of the Federation, it was thought that suitable arrangements could be made for their affiliation. This is in keeping with the action taken by the Board of Control in the 1930 Annual Meeting, making it possible for such interested persons to receive the SEWAGE WORKS JOURNAL at the rate of $1.00 yearly plus the foreign postage, it being then decided to try out this arrangement for a period of two years. Since as was explained by the Chairman, none of these groups was now ready to affiliate, although the prospects for this were good, it was moved and seconded, the motion carrying, that the arrangement previously made be extended.

Editor Mohlman had written to Chairman Emerson, suggesting that the allotments for the year 1932 for the abstracting work carried on by Mr. Streeter be in the sum of $200.00, and upon motion which was seconded and carried, this amount was allotted.

The Ohio Sewage Works Conference Group made formal application for affiliation with the Federation, and upon motion duly made, seconded and carried, this application was accepted, and affiliation approved.

The Board next discussed the matter of increasing the issue of the SEWAGE WORKS JOURNAL from four numbers now issued quarterly, to six numbers issued bi-monthly. Upon assurance from Business Manager Buffum that the finances of the Federation would permit this expansion, it was moved and seconded, the motion carrying, that the recommendation to this effect made by F. W. Mohlman, Editor, be adopted and authorization be given to issue the JOURNAL in six numbers during the forthcoming year.

The financial budget for 1932 was presented, and after discussion, upon motion duly made, seconded and carried, the budget as presented was adopted.

The Board then proceeded to the election of officers for the ensuing year. Upon motion which was duly seconded and carried the following were elected: C. A. Emerson, Jr., the present Chairman; Abel Wolman, the present Vice-Chairman; and William W. Buffum, the present Business Manager, were re-elected for the year 1932. H. E. Moses, the present Secretary-Treasurer, was re-elected for 1932 and 1933.

Members-at-Large: William W. Buffum, H. W. Streeter, J. R. Downes, William J. Orchard, John. F. Skinner.

Upon motion duly made, seconded and carried, the Executive Committee as existing was continued for the forthcoming year. This comprises: C. A. Emerson, Jr., *Chairman;* Abel Wolman, William W. Buffum, William J. Orchard, H. E. Moses, *ex-officio.*

Pursuant to the provisions of the constitution and by-laws, the following committees were selected, and upon motion duly made, seconded and carried, they were approved:

Membership Committee: H. W. Streeter, *Chairman,* Cincinnati, Ohio; Stuart E. Coburn, Boston, Mass.; W. Scott Johnson, Jefferson City, Mo.

Publication Committee: John F. Skinner, *Chairman,* Rochester, N. Y.: Charles G. Hyde, Berkeley, Cal.; William Rudolfs, New Brunswick, N. J.; R. E. Tarbett, Washington, D. C.; F. W. Mohlman, *ex-officio,* Chicago, Ill.

Coördination Committee: V. M. Ehlers, *Chairman,* Austin, Texas; F. H. Dryden, Salisbury, Md.; C. D. McGuire, Columbus, Ohio.

Research Committee: Earle B. Phelps, *Chairman,* New York City; Willem Rudolfs, New Brunswick, N. J.; Abel Wolman, Baltimore, Md.; W. S. Mahlie, Fort Worth, Texas; J. W. Bugbee, Providence, R. I.

There being no further business, upon motion, the Board adjourned.

H. E. MOSES, *Secretary-Treasurer*

Sewage Research

Heat and Energy Relations in the Digestion of Sewage Solids
I. The Fuel Value of Sewage Solids

By Gordon M. Fair and Edward W. Moore

Associate Professor of Sanitary Engineering and Research Assistant in Sanitary Engineering, The Harvard Engineering School, Cambridge, Massachusetts

The interchanges of heat and energy which occur during the digestion of sewage solids have been under study for a number of years in the Laboratory of Sanitary Engineering of the Harvard Engineering School. In connection with this work, numerous analyses have been made of the fuel values of raw and digested sewage solids produced by plain sedimentation (called fresh sludge in this paper) and by the activated-sludge process. The results of these analyses, supplemented by the findings of other workers, are of interest, particularly when studied in their relation to the volatile matter content of the sewage solids, as determined by the loss-on-ignition test.

Some work on the fuel values of sewage solids from the Chicago stockyards was done by Wisner and Pearse[1] in 1914 to test the possibility of utilizing these values in a practical way in the disposal of sludge by burning. In 1930, Bach [2,3] reported the fuel values of fresh and digested solids from the Emscher District and from Munich, Germany, in connection with the mooted question of the self-heating of sludge during digestion and employed calorimeter tests in studying the digestibility of Imhoff-tank scum. In 1931, Pearse and Mohlman[4] secured information on the fuel values of a number of different sludges from Chicago sewage-treatment works, again in relation to the disposal of sludge by incineration.

The analyses obtained by Wisner and Pearse (9 values), Bach (41 values), Pearse and Mohlman (11 values) and the authors (56 values) are recorded in the accompanying figure. As there shown, a plotting on double-logarithmic coördinates of the calorific values of sewage solids against their percentage loss-on-ignition yields a scatter diagram in which the points array themselves in a well-defined and straight band whose slope is significantly greater than 45 degrees. This band is readily defined by four lines—two inclusive ones and two central or average ones—characterized by the equation:

$$Q = CP^n$$

in which

Q = fuel value in B. t. u. per pound of dry solids;

P = percentage loss-on-ignition or percentage volatile, or organic, matter in the sewage solids;

C and n = coefficients related to the energy content of the volatile matter.

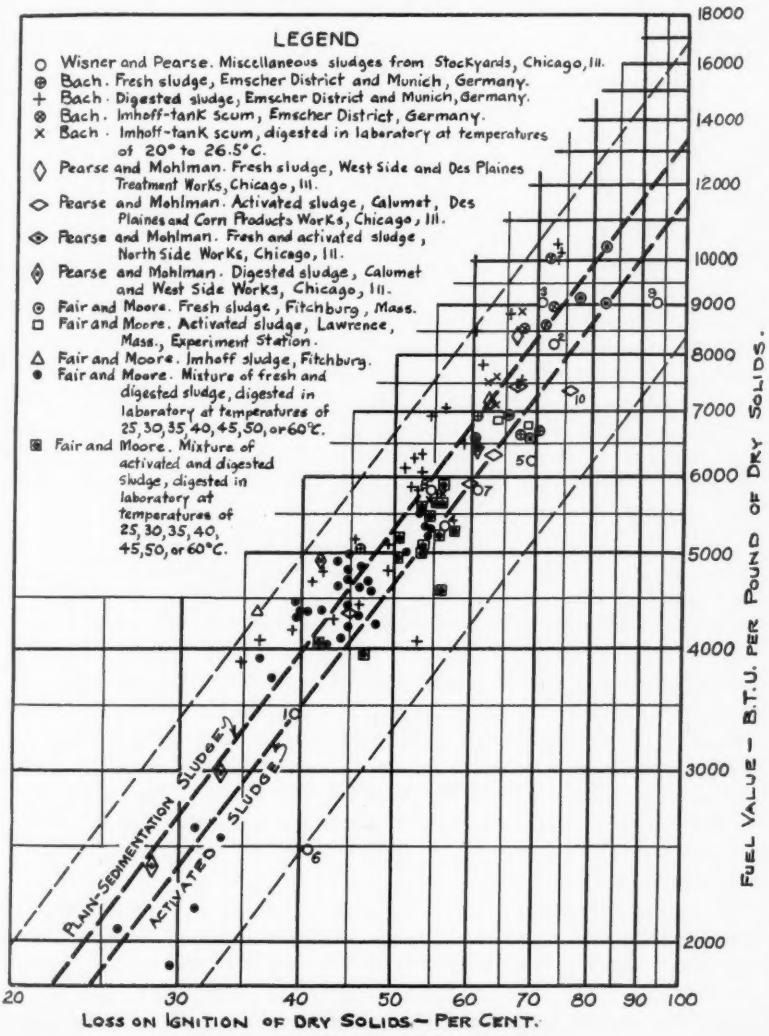

LEGEND
Wisner and Pearse. Miscellaneous sludges from Stockyards, Chicago, Ill.
Bach. Fresh sludge, Emscher District and Munich, Germany.
Bach. Digested sludge, Emscher District and Munich, Germany.
Bach. Imhoff-tank scum, Emscher District, Germany.
Bach. Imhoff-tank scum, digested in laboratory at temperatures of 20° to 26.5°C.
Pearse and Mohlman. Fresh sludge, West Side and Des Plaines Treatment Works, Chicago, Ill.
Pearse and Mohlman. Activated sludge, Calumet, Des Plaines and Corn Products Works, Chicago, Ill.
Pearse and Mohlman. Fresh and activated sludge, North Side Works, Chicago, Ill.
Pearse and Mohlman. Digested sludge, Calumet and West Side Works, Chicago, Ill.
Fair and Moore. Fresh sludge, Fitchburg, Mass.
Fair and Moore. Activated sludge, Lawrence, Mass., Experiment Station.
Fair and Moore. Imhoff sludge, Fitchburg.
Fair and Moore. Mixture of fresh and digested sludge, digested in laboratory at temperatures of 25, 30, 35, 40, 45, 50, or 60°C.
Fair and Moore. Mixture of activated and digested sludge, digested in laboratory at temperatures of 25, 30, 35, 40, 45, 50, or 60°C.
PLAIN-SEDIMENTATION SLUDGE
ACTIVATED SLUDGE
18000
16000
14000
12000
10000
9000
8000
7000
6000
5000
4000
3000
2000
FUEL VALUE — B.T.U. PER POUND OF DRY SOLIDS.
20
30
40
50
60
70
80
90
100
LOSS ON IGNITION OF DRY SOLIDS — PER CENT.

FIG. 1. Colorific Value of Sewage Sludge.

Two central or average lines are employed instead of a single one because there is a marked differentiation between the average values for fresh or digested fresh solids and the average values for activated or digested activated solids. As more information is accumulated, it will probably be possible further to define the characteristics of sludges of different origin.

The lines chosen by the authors to generalize the information are parallel. The exponent n of P is, therefore, a constant, but C varies. The equations of the four lines are:

Upper inclusive line Q	$= 36P^{4/3}$
Average fresh-sludge line Q	$= 29P^{4/3}$ (including digested fresh sludge)
Average activated-sludge line Q	$= 25P^{4/3}$ (including digested activated sludge)
Lower inclusive line Q	$= 18P^{4/3}$

A study of the plot and the equations suggests a number of interesting deductions and speculations. Most useful, perhaps, is the observation that the plot gives a means for estimating the fuel value of sewage solids from their loss on ignition. So far as the recorded values are concerned, this estimate generally lies within 12 per cent of the true magnitude when the origin of the sludge is known. Departures in excess of 12 per cent can, in most instances, be explained as due to special circumstances. Thus the marked points 5, 6 and 7 represent air-dried sludges for which the loss on ignition test was made a month prior to the calorimeter test; point 9 relates to a sample of stockyard screenings rather than a sample of sewage sludge; point 10 represents an activated sludge from corn-products wastes; a number of Bach's high points refer to sludges from a coal-mining region which, as he states, probably contain some coal dust. In the light of these explanations, the wide variation in fuel values relative to the loss on ignition between the inclusive lines loses much of its significance.

So far as differences between raw and digested sludges are concerned, the plot indicates that these two classes of sludge fall into overlapping regions. In general, however, it appears that raw sludges contain more than 60 per cent organic matter and have calorific powers in excess of 7000 B. t. u. per lb. of dry solids in the case of fresh sludges, and 6000 B. t. u. per lb. of dry solids in the case of activated sludges, while the values for digested sludges lie below these figures. It should be noted that in relatively few instances has digestion carried the loss on ignition below 35 per cent and the fuel value below 3500 B. t. u. per lb.

Extrapolation of the fitted lines to 100 per cent loss on ignition places the average fuel value of the volatile matter of fresh solids at 13,500 and that of activated solids at 11,600 B. t. u. per lb. of dry solids. These figures compare favorably with the values of commonly used fuels and show why dewatered sludges of high volatile-matter content burn freely when ignited.

If we examine the equation of the lines, we note that the coefficients C

and n which, as previously stated, are related to the energy content of the volatile matter in sewage sludge, define this characteristic in somewhat different ways. The coefficient n which records the *slope* of the lines, seems to define the relative energy content of high and low volatile-matter sludges of the same or similar origin, and also the relative energy content of digested and undigested sludges of a given origin, while the coefficient C, which records the *position* of the lines, appears to define the relative energy content of sludges of equal volatile-matter content but of different origin.

With reference to the coefficient n, which in accordance with our choice is constant at a value of $^4/_3$, the dependence of the fuel value of sludges of the same or similar origin not on P, but on $P^{4/3}$, shows first of all that the idea, heretofore quite prevalent, that the fuel value per unit of volatile matter should be relatively constant is unfounded. Fuel value per unit weight of volatile matter decreases sharply with the percentage volatile-matter content of the sludge, the magnitude of variation being illustrated by the following values based upon the authors' average curves:

Volatile Matter, %	Fuel Value = B. t. u. per Pound Dry Volatile Matter	
	Fresh* Sludge	Activated* Sludge
100	13,500	11,600
90	13,000	11,200
80	12,500	10,800
70	11,900	10,300
60	11,300	9,800
50	10,700	9,200
40	9,900	8,600
30	9,000	7,800

*Raw or digested.

Since the volatile-matter content of sewage solids of a given origin decreases during digestion, the dependence of fuel value upon $P^{4/3}$ shows furthermore that it is the organic matter of the highest calorific power, probably grease, carbohydrates and proteins, that is attacked in the digestion process. For convenience these substances will be termed "high-energy" compounds. Raw, or undigested, sludge contains a relatively large proportion of these high-energy compounds whose anaerobic decomposition yields energy liberated as combustible gas, largely methane. The higher, therefore, the volatile-matter content of undigested sludge of the same or similar origin, the greater may we suppose will be the energy yield during digestion.

It should be noted, in passing, that the magnitude of the exponent n of P may depart appreciably from the selected average value of $^4/_3$. The lines recording the reduction in fuel value relative to volatile matter during digestion may be steeper ($n > {}^4/_3$) or flatter ($n < {}^4/_3$). This signifies that the energy content of the organic matter digested is, respectively, higher or lower than the average, within the range of average percentages of loss on ignition.

As shown in the plot, sludges of dissimilar origin may possess the same volatile-matter content and yet differ in fuel value; this difference is defined by the coefficient *C*. The higher the value of *C*, the greater is the relative calorific power, or content of high-energy compounds, of a sludge yielding a given percentage loss on ignition. So far as the plotted observations go, sludge resulting from plain sedimentation of sewage has an average *C* value of 29, while sludge produced by the activated-sludge process has one of 25. In other words, the fuel value of fresh solids, or their content of high-energy compounds, averages 16 per cent greater than that of activated solids. If more information were available, similar average differences in *C* could possibly be found for different types of sewages, notably domestic, storm and industrial sewages. In this connection it should be noted that abnormal quantities of mineral matter in a sewage will increase the coefficient *C* of the sludge, *i. e.*, the fuel value of the sludge will appear to be abnormally high. The reason for this is that addition of mineral matter reduces the percentage loss on ignition but does not affect the energy content of the organic matter. Hence, the fuel value of the resulting sludge becomes high relative to the loss on ignition and is reflected in a high value of the coefficient *C*.

Conclusion

The empirical relationship, established in this paper between fuel value and loss on ignition, may evidently be employed to advantage for two purposes:

1. To estimate the fuel value of sewage solids from their loss on ignition.
2. To assist in interpreting the difference of behavior of sewage solids during digestion.

References

[1] George M. Wisner and Langdon Pearse, "Report on Industrial Wastes from the Stockyards and Packingtown in Chicago," 1914, p. 129.

[2] H. Bach, "Selbsterwärmung des Klärschlamms," *Technisches Gemeindeblatt*, **33,** 108 (1930).

[3] H. Bach, "Über Gasungsfähigkeit von Schwimmschlamm," *Gesundheits-Ingenieur*, **53,** 790 (1930).

[4] Langdon Pearse and F. W. Mohlman, Private communication to the authors, January, 1932.

The Effect of Gases on Sewage Sludge Digestion

BY C. E. KEEFER AND HERMAN KRATZ

Principal Assistant Engineer and Junior Chemist, Bureau of Sewers, Baltimore, Md.

In the study of sludge digestion a number of environmental factors affecting the speed of digestion have been investigated. Little, if any, work has been done, however, to determine what effect certain gases might have on the decomposition of sludge. While sewage solids are digesting, they are in intimate contact with the gases of decomposition, which include large amounts of methane, carbon dioxide and nitrogen, and small quantities of hydrogen and other gases. Moreover, sludge in uncovered digestion tanks is in contact with oxygen and nitrogen in the atmosphere. It is therefore of interest to know what effect these gases have on digestion. It is believed by some that carbon dioxide inhibits digestion, partly by tending to produce an acid reaction. The circulation of sludge in digestion tanks by pumping has been advocated in order to release carbon dioxide and to promote bacterial activity. It has also been suggested that digestion tanks be designed so that the atmosphere will not come in contact with the sludge, the thought being that oxygen inhibits anaerobic decomposition.

In order to determine the effect of various gases on sludge digestion, a series of laboratory experiments was conducted at the Baltimore sewage works. Known quantities of gases, including air, oxygen, nitrogen, carbon dioxide, methane and sludge gas, were bubbled up through sewage sludge, and the rate of digestion as determined by the quantity of gas produced was observed. The experiments indicated that neither oxygen nor carbon dioxide in the quantities used was detrimental to sludge digestion. Somewhat more rapid digestion and larger quantities of methane and total gas were evolved when nitrogen and methane were used.

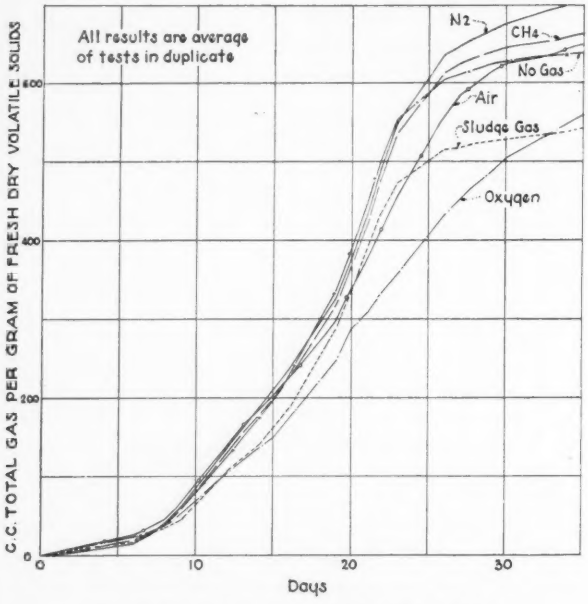
Method of Conducting Experiments

An extended series of experiments was conducted. Of these the first two were preliminary in character, and served to indicate the technique to follow in subsequent work. The results of the last two sets of experiments are given, and are designated "Series No. 1" and "Series No. 2."

The raw sludge used for the experiments was collected from the preliminary settling tanks at the Baltimore sewage works. These tanks treat a domestic sewage, which comes from a separate system of sewers, and which has passed through screens with $^{7}/_{8}$-inch openings. The solids as they were removed from the tanks were about a week old with pH values varying from 4.9 to 5.2. The seeding material, which was obtained from one of the digestion tanks at the Baltimore works, was well digested with a

pH value ranging from 7.1 to 7.2 and a volatile matter content varying from 52.6 to 54.9 per cent.

The two materials were mixed in the ratio of two parts by weight of raw solids to one part of ripe material, the said weights being based on the dry volatile solids in the two sludges. The weight of the mixture put in each of a number of Woulff bottles was 2.27 lb. In the bottom of each bottle was a coil of $^1/_4$-in. rubber tubing, in which there were a number of small perforations. The hose passed out of the bottom to the bottle through a sealed



SERIES No. I. TOTAL GAS PRODUCTION FROM SLUDGE TREATED WITH VARIOUS GASES

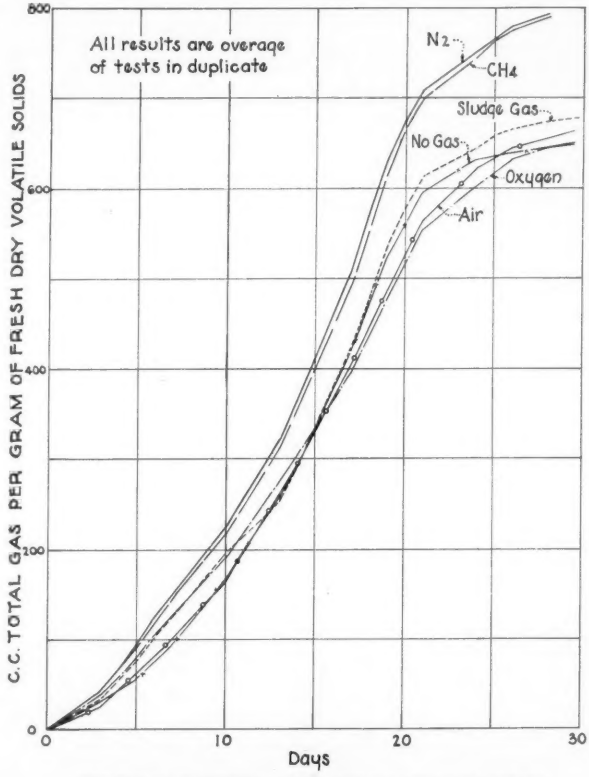
FIG. 1

opening, and was connected to the source of gas supply. Gas was introduced into the hose under a slight pressure, and flowed up through the sludge in a number of small bubbles. The quantity of gas that passed through each bottle amounted to 19,000 cc. daily. The sludges were incubated at 28° C. ± 1°. The rate of digestion was determined by the volume of gas given off by the sludge. The gas generated was measured and analyzed each day. The gas volumes have been reduced to 0° C. at a pressure of 760 mm. of mercury. During the entire experiment duplicate samples of sludge were treated with the various gases, and the quantities

of gas produced as given in Figures 1, 2 and 3 represent the average of these duplicate tests.

Results of Experiments

Series No. 1.—In the first series of experiments the total gas from all of the sludges was collected and measured, including the control, to which



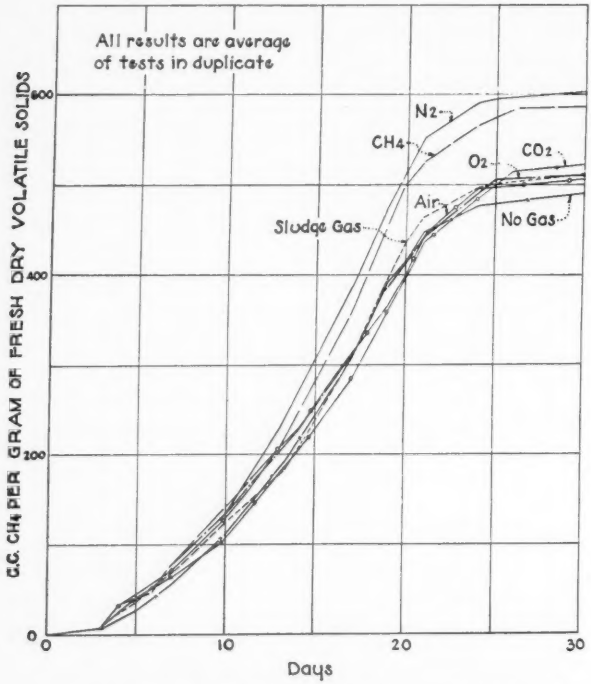
SERIES No. 2. TOTAL GAS PRODUCTION FROM SLUDGE TREATED WITH VARIOUS GASES

FIG. 2

no gas was added. These quantities are shown in Figure 1. The total gas collected from the control and from the sludges treated with N_2 and CH_4 was about the same during the first 25 days. After that the sludge treated with N_2 produced slightly more gas. The digestion of the sludge treated with air was slightly lower than the digestion of the above-mentioned sludges.

The rate of digestion of the solids treated with sludge gas was about the same as that treated with air. After the twenty-fifth day, however, the rate of digestion was much less. The sludge treated with oxygen digested more slowly than any of the other materials.

Series No. 2.—The results of the second series of experiments are given in Figures 2 and 3, which show the quantities of total gas and methane produced per gram of fresh dry volatile solids from each of the sludges. In



SERIES No.2 TOTAL METHANE PRODUCTION FROM SLUDGE TREATED WITH VARIOUS GASES

FIG. 3

these tests the best results were obtained with nitrogen and methane. These two gases each produced about 800 cc. of total gas and 600 cc. of methane per gram of fresh dry volatile solids as compared with the control, which evolved about 650 cc. of total gas and 500 cc. of methane. The total gas and methane production from the sludges treated with oxygen, air, sludge gas and carbon dioxide were about the same in volume and rate of generation as from the control.

Results

Although a close study of the experiments indicates that the results are not entirely uniform, it would seem that the sludges treated with nitrogen and methane digested most rapidly. It is believed that the benefits from these two gases were chiefly that they served to agitate and mix the sludge. The results obtained by the use of carbon dioxide, as indicated by the production of methane, compared favorably with the control. Although the digestion of the sludge treated with oxygen in the first series of experiments was somewhat slower than that of the other sludges, the digestion of the sludge treated with oxygen in the second series compared favorably with the sludges treated with air, carbon dioxide, sludge gas and with the control.

The Baltimore sewage works are under the general direction of B. L. Crozier, chief engineer, George E. Finck, sewerage engineer, and G. K. Armeling, superintendent. Acknowledgments are due to J. W. Bushman, who assisted in conducting the experiments.

Chlorination of Sewage for Oxygen Demand Reduction*

Round Table Discussion, Opened by LINN H. ENSLOW

Research Engineer, The Chlorine Institute, Inc., New York City

When chlorine is added to sewage or sewage effluent, for whatever purpose, at least 90 per cent of the total quantity applied disappears immediately. Eventually, of course, all of it is transformed from its active or oxidative state to inert chlorides. One naturally inquires as to what happens to the chlorine which is absorbed and what is its ultimate effect on the constituents of sewage.

To this question there is one broad answer, *viz.*, the oxidative chlorine has such an affinity for reducing organic and inorganic compounds present in the sewage that it promptly attacks such compounds even before it has an opportunity to destroy the living bacteria present. Beyond the fact that it has been proved that chlorine destroys the oxygen-consuming hydrogen sulphide and such simple compounds as urea, if present, there is little of a concrete nature that is known concerning the reactions and the by-products produced when chlorine is added to sewage. One thing that is known is that chloramines are produced when the chlorine is added as an alkaline hypochlorite or in combination with lime, and the same is true when chlorine water is added to an alkaline sewage. Another thing that has been disclosed by studies made in the Cincinnati laboratories of the United States Public Health Service is that chlorination actually destroys the bodies of bacteria. That is to say, the dead bodies of the organisms cannot be detected after chlorination. One might suppose that the bacteria, most of which are largely composed of amines, are converted into a soluble product as a result of the chlorine attack and thus disappear as such.

There is ample laboratory evidence to show that chlorination of many organic compounds closely allied to compounds present in sewage effluents, results in the production of end-products entirely different in nature from the original material. While the reaction is of a nature classified as an oxidation phenomenon, it might also be classed as a "chloridizing" effect which results in chloro-compounds being produced in distinction to oxidation end-products. Indications point to the probability that such chlorinated organic products are in many cases non-assimilable by organisms which can use the original material as a food supply. Further than that, these products act toxically on organisms introduced into highly diluted portions of such chlorinated products. For sake of illus-

* *Presented at the Fourth Annual Meeting of the New York State Sewage Works Association, New York City, January 19, 1932.*

tration, I shall refer to one specific instance wherein studies were attempted by Dr. Rudolfs and his co-workers, in which a diluted culture medium (nutrient broth) was chlorinated to varying degrees. The diluted broth had a 5-day oxygen demand value of roughly 200 parts per million. The same after chlorination and subsequent dilution, then reseeded with domestic sewage, would not support the organisms thus introduced, and in fact slowly killed them off to such an extent that the oxygen demand value could not be determined by the standard procedures employed in determining the oxygen demand of the broth dilutions which had been sterilized by heat. There was no excess chlorine present in the broth dilutions which could be detected by any of the known methods; not even by the acidic starch-iodide test.

Nutrient broth contains beef extract (proteins), peptone and lactose. Since chlorine has very little power to attack lactose, it is evident that the attack was exerted on the nitrogenous protein and peptone. From what has been observed on a practical scale when chlorinating poorly nitrified sewage effluents, it may be assumed that the compounds susceptible of yielding albuminoid ammonia in laboratory tests were attacked most specifically. Dr. F. E. Hale has published annual figures covering sewage chlorination at Mt. Kisco and New Bedford, N. Y., showing the effect that chlorine exerts in converting "albuminoid ammonia" in sewage effluents into some compound that no longer yields the same quantity of ammonia when the albuminoid determination is applied.

Whatever may be the exact reactions between chlorine and the contents of settled sewage or industrial waste remains open to argument, but it seems to be conclusively demonstrated by no less than sixteen independent investigators that chlorinated sewage or industrial waste will no longer support biological development to the same extent as it does prior to chlorination, and as a consequence an actual reduction of oxygen demand results. Further than this there is an important effect produced which materially retards the *rate* at which oxygen depletion in diluted samples will proceed. It seems apparent that the actual reduction of oxygen demand values results from reactions on products in the non-settleable portion of sewages, especially on the soluble or colloidal products. This effect is not alone obtainable on the 5-day demand but is equally effective on the longer period demands, at least up to 20 days.

The Amount of Oxygen Demand Reduction

The amount of reduction in oxygen demand is not great, averaging on the whole between 25 and 35 per cent of that originally present in the non-settleable portion of the sewage, prior to chlorination. I should not speak of settled sewage alone because it is now common practice to add chlorine ahead of settling tanks and the end result is the same, if not more

pronounced, than when chlorine is applied to the settled sewage. If the sewage is quite strong, for instance, if it should contain organic industrial wastes, then the amount of oxygen demand reduction secured by chlorination increases, and this in parallel with the increase in the chlorine demand of the sewage or waste. An extreme case of this kind is found in chlorination of packing house wastes wherein 200 to 250 parts of chlorine may be consumed and the oxygen demand reduction is tremendous. Herein also is an instance where it is very difficult to get organisms, which are necessary in determining the biochemical oxygen demand, to live in the diluted chlorinated waste.

In the experimental work conducted by Mohlman, Hurwitz and Ruchhoft of the Chicago Sanitary District, representing perhaps the most painstaking and thorough studies yet made on this subject, the sewage was of only medium strength but the average reduction of oxygen demand observed was 24.7 parts per million, which was the same or greater after 20-day incubation periods. The average chlorine dosage involved in the Chicago studies was 10.9 parts per million and the reduction of oxygen requirement was approximately 2 parts for every part of chlorine added. An interesting side light on that observation is the fact that if one was considering the quantity of the oxygen that could possibly be produced by that quantity of chlorine (according to the well known reaction $Cl_2 + H_2O = 2HCl + O$) the greatest possible oxygen demand reduction would have been in the ratio of 16 oxygen to 70 chlorine by weight, and 1 p. p. m. chlorine could only have reduced the oxygen demand by a possible 0.228 part per million. The reduction actually secured was 9 times $\left(\frac{2}{0.228}\right)$ that accountable for, if the nascent oxygen theory were applied. These results suggest more than ever that the "chloridizing" theory is most probably the correct one to account for the observed oxygen demand reductions.

The Practical Aspects of Chlorination for Oxygen Demand Reduction

More than two years ago H. G. Baity, as the result of studies made at the University of North Carolina, discussed the use of chlorination at sewage plants for production of effluents less likely to produce nuisance in streams than that produced by unchlorinated effluents. He stressed the economy of providing for chlorination in certain instances, where otherwise more expensive methods of treatment might be required to serve the same purpose, for a few months annually when stream flow would be at its low point. Baity's opinions have since been corroborated by several other investigators.

To test the correctness of his assumptions, plant scale experimentation was conducted at Chapel Hill, N. C., during the drought period of 1930.

Stream data, analysis of a large number of stream samples and observations of value were readily procured because of the continuous dry period. The results with and without chlorination of the settled sewage were carefully kept and several periods with and without chlorination were covered. The laboratory findings on stream samples collected indicated the improvement in terms of oxygen content and biochemical oxygen demand values in the stream below the sewage plant. Upon publication of the Chapel Hill results concrete data will be available which will represent the most conclusive of all hitherto reported investigations. It represents a critical study of actual effects under natural conditions in a small sluggish stream, the flow of which at times barely exceeded the settled sewage in volume. On the strength of these results chlorination is employed during low stream flow periods to supplement the sedimentation process at Chapel Hill.

The results reported recently on plant scale prechlorination at Dayton, Ohio, by Tatlock are also convincing. Imhoff tanks and chlorination at Dayton have produced an over-all oxygen demand reduction of 55 per cent and better. At one period the reduction was 67 per cent, but that was secured before turning a strong septic sewage into the plant.

At Austin, Minn., convincing results have been reported from superchlorination of packing plant wastes followed by sedimentation in tanks equipped with Dorr mixing and clarifier mechanisms. Protein and fat separate out, as the result of heavy chlorination, and are removed. The effluent contains excess chlorine, has an oxygen demand value of approximately 150 p. p. m. and is clear. It is discharged into the river at the rate of about 700,000 gallons per day. The stream has been improved markedly, and it has been reported that fish are now in the river below that plant for the first time in years.

The Los Angeles County Sanitation District has made effective use of chlorine for improving conditions in a tidal estuary, but I have no exact records covering this situation. In addition there have been several smaller works which have adopted chlorination for oxygen demand reduction.

Unfortunately in one or two instances chlorination has been tried where evidence was indicative that better removal of solids from the sewage would have been of first importance, and satisfactory clarification possibly would not have been sufficient, even with chlorination, to meet the severe conditions existing in the stream below the plant. Chlorination has limitations which must be recognized.

Of all the circumstances under which chlorination will serve as an adjunct for improving plant effluents, the most practical seems to be its application at such times as stream flows become inadequate to assimilate the normal effluent without nuisance production or creation of unsightly

conditions in the stream. Particularly will this apply during the dry months of fall, whereas the flow in the stream may be entirely adequate at other times to dilute the effluent properly without further treatment. It therefore may no longer be necessary to provide treatment works to meet requirements during absolute minimum stream flows. As an example of this, there are instances where solids removal by sedimentation, which provides 30 to 40 per cent purification, would serve during the major portion of the year; if supplemented by chlorination to secure an over-all oxygen demand reduction of 50 to 60 per cent during a minor portion of the year, all requirements should be satisfied.

Should a somewhat greater degree of purification be required chemical precipitation, with chlorination for short periods, may be used, without providing any additional units to the existing sedimentation plants. The oxygen demand may be reduced thereby by 70 to 75 per cent with certainty and a more pleasing effluent to the eye will likewise result.

An added advantage from chlorination is the considerable retardation of biological action which is secured, and which produces moderation in the rate of oxygen depletion in waterways. This effect will produce the same results as does cold weather, *i. e.*, allow the sewage to flow farther down stream to meet added dilution before oxygen in the receiving stream can be depleted. Or perhaps the case might be one of dilution by tidal action, in which case retarded biological activity would allow an increased number of tidal dilutions and a greater movement seaward before oxygen depletion will have proceeded to the otherwise normal extent observed in hot weather, as compared to that observed in cold weather. Use of the "lime chlorine" process is particularly advantageous for delaying biological activity.

Cost Estimates

I am frequently asked concerning the relative cost of providing chlorination as against biological treatment. The over-all operating cost per year of chlorination will be about one-tenth that of sprinkling filters. The cost of operation of activated-sludge plants varies so that a valid comparison cannot be made.

The chlorine involved will cost between $2.20 and $3.75 per million gallons at sewage works treating 3 million gallons per day and upward. The lower figure applies with present chlorine prices in ton containers. For plants treating between 1.5 and 3.0 million gallons per day, the cost per million gallons will be between $3.60 and $5.50 (with chlorine purchased in cylinders). Spreading cost for 120 days of chlorination over the year naturally reduces the average cost to 33 per cent of the costs shown; or say 75 cents to $1.25 as the annual average cost per million gallons at the plants of 3 m. g. d. capacity or more.

Discussion

BY WILLIAM T. CARPENTER

Chemist, Sanitary Commission, City of New York

Mr. Enslow has asked me to discuss the results of a rather sketchy study made in 1928 and 1929 on the effect of chlorine on the B. O. D. of screened sewage. The circumstances of the work, insufficiency of personnel, absence of any kind of proper laboratory, etc., made the reliability of the results less than I should have liked to have. It was impossible to hold the temperature of the improvised laboratory even approximately at 20° C. so that the absolute values of B. O. D. are not so good as the figures for percentage reduction, where the same errors entered into all samples.

The experiments were conducted at the Jamaica Disposal Works in the Borough of Queens, New York City. The domestic sewage from a fairly large area is passed through disk screens 26 ft. diameter with 3/32 in. slots, after which it is pumped through a 51-in. wood stave pipe about a mile long to Jamaica Bay. The chlorine is introduced into the force main just subsequent to pumping. The pumps act intermittently as the water rises in the well. The chlorinators start and stop operation simultaneously with the pumps. An annoying phenomenon develops as a result of this. While the pump is increasing in speed and volume pumped, the chlorine is entering at the steady designated rate, thus resulting in an intense overchlorination for a minute or two. In taking the samples for this study, particular care was used to get them when the pump had got up to speed. The time of passage through the wood stave pipe was ascertained by the use of dye to be 35 minutes, more or less.

At the time of the chlorine experiments, the tributary area was somewhat thinly populated and this was reflected in the character of the sewage. A 24-hour run on December 23, 1927, some four months before this work was started, yielded 88 p. p. m. as the total suspended solids figure, and the total quantity pumped was but 12 m. g., the plant being designed to screen 80 m. g. d. The chlorine demand appeared to stand quite constantly near 6 p. p. m.

The conduct of the work was as follows: A sample was taken from the first manhole on the pipeline and rushed to the laboratory, where a residual chlorine test and a dilution for B. O. D. were made at once, the total time consumed between application of chlorine and dilution being about 5 minutes. This sample was then held for 35 minutes, after which a second residual test and dilution were made. This procedure was for the purpose of learning whether or not a prolonged period of contact was of material advantage. After dilution the B. O. D. samples were seeded with crude sewage. Table I gives the results as found according to the above described procedure.

In examining this table the eye is attracted by several inconsistent figures, but in the main they vary as would be expected. The three averages at the bottom appear to have evened out the individual irregularities. One point of outstanding practical importance is brought out, and that is that the chlorine appears to do its work without an extended contact period. The residuals once established diminish but little, or not at all, in the period from 5 minutes to 40 minutes. The average reduction in B. O. D. is practically the same after 5 minutes as after 40 minutes.

TABLE I

Date	Hour	Screened Sewage B. O. D., P. p. m.	Rate of Cl Appl., P. p. m.	Chlorinated Sewage — After 5 Min. Resid. Cl, P. p. m.	After 5 Min. B. O. D., P. p. m.	After 40 Min. Resid. Cl, P. p. m.	After 40 Min. B. O. D., P. p. m.	Remarks
1928								
5/3	12 M.	80	5.4	0.2	29	0	33	
5/10	11:30 A.M.	49	6.2	0.0	24	...	..	
5/11	2:00 P.M.	61	6.2	1.2	22	1.2	13	
5/16	11:30 A.M.	71	6.2	0.4	20	0.4	18	
5/17	2:45 P.M.	78	5.2	0.3	34	0.2	32	
1929								
2/8	11:00 A.M.	73	2.9	0	49	0	48	
2/13	11:30 A.M.	52	2.9	0	48	0	40	
2/15	10:45 A.M.	41	2.9	0	77	0	77	
2/20	11:10 A.M.	44	2.9	0	24	0	25	
2/27	11:15 A.M.	97	2.9	0	51	0	47	
3/1	10:45 A.M.	81	2.9	0	85	0	84	
3/6	11:25 A.M.	92	2.9	0	60	0	36	
3/8	11:20 A.M.	48	2.9	0	72	0	102	
3/13	11:50 A.M.	100	2.9	0	105	0	69	
3/15	11:00 A.M.	94	5.8	0.4	57	0.3	66	
3/20	11:55 A.M.	144	5.8	0	114	0	106	
		77	5.8	0.5	32	0.5	32	Av. samples with resid.
		83	3.2	0	70	0	70	Av. samples without resid.
		81	4.2	0.23	56	0.13	54	Av. of all

These results would indicate that chlorine applied to this fine-screened sewage up to half its demand will cut the B. O. D. some 15 per cent, and applied to a distinct residual will reduce it nearly 60 per cent.

The publication of these results has been delayed for three years in the hope that we should be able to amplify the work, which was broken off before we were through with it, but it seems desirable to contribute it now as part of accumulated experience.

So now I give these figures to the brotherhood as Hamlet's father was sent to his reckoning, with all his imperfections on his head.

Discussion

BY FRANK E. HALE

Director of Laboratories, Department of Water Supply, Gas & Electricity, New York City

Mr. Carpenter's remarks that sludge precipitation by excess chlorine is not new, but was known to a Mr. Brown who worked for Dr. D. D. Jackson, requires further enlightenment. Mr. Brown merely passed on information, which I had obtained many years before for Dr. Jackson. At that time he had a problem of purifying a trade-waste from Massachusetts. We found that chlorination would reduce the high color, and in excess cause heavy precipitation of sludge, thus clarifying the waste. The time was long before chlorine had come into use to purify sewage or water supply. We found further that the amount of chlorine required was sufficient to neutralize the alkalinity and that similar results could be obtained by the use of acid for this purpose. I was personally acquainted with the well-known engineer and inventor, Elmer E. Sperry, recently passed on and of whom many of you know. The question of the use of chlorine for the above purpose depended upon cost. We took the matter up with Mr. Sperry and learned from him that chlorine was a by-product, or at that time waste product of the soda industry, and could be obtained in quantity at the mere cost of compression. We opened up the possibilities of the large use of chlorine in purifying sewage and water supply, but after due consideration Mr. Sperry reached the conclusion that the prospects were not big enough. In view of the extensive development of chlorine for these purposes since that time, the above seems of historical interest.

With regard to the precipitation of proteid by excess chlorine, cited by Mr. Enslow as recently experienced in Austin, Minnesota, I would call your attention to the fact that the quantitative method, known to any biological chemist, of determining proteid in milk is to acidify slightly with acetic acid. As chlorine in excess produces acidification, why should the proteid not be precipitated? It would naturally be expected.

Too much mystery is made of the action of chlorine. It may be considered to react in two general ways: as an oxidizer and as an acidifier. Oxygen and chlorine are elements of very similar properties. Both react with all of the same elements, with one or two exceptions. Carbonaceous matter may be burned by either oxygen or chlorine. The end-product with oxygen is carbon dioxide. The end-product with chlorine is carbon tetrachloride. That is why the latter is non-explosive and non-combustible, since it is the end-product of the combustion of carbon in chlorine. If a piece of filter paper is soaked in turpentine and suspended in a flask of chlorine gas, it will take fire spontaneously and burn up in

the chlorine. On the other hand, when chlorine reacts with the hydrogen of water to furnish oxygen for oxidation, hydrochloric acid is formed. This, of course, is neutralized by the alkalinity of sewage or water to the extent of the alkalinity present. Chlorine in excess will, therefore, cause acidity, and this acidity in addition to the bleaching action on organic matter will frequently cause precipitation of colloidal matter and will also cause an apparent reduction in color due to changing the color to an acid condition. This reduction in color is not permanent but returns on addition of alkali again. In other words, the color acts as an indicator does. (In this connection see "The Relation between Aluminum Sulphate and Color in Mechanical Filtration," *J. Ind. Eng. Chem.*, p. 632 (1914)). In ordinary chlorination all of the chlorine becomes fixed in combination with the calcium of the alkalinity and is present as calcium chloride. This we have proved by many years' experience by determination of the fixed chlorine before and after chlorination. The increase in fixed chlorine corresponds in yearly averages with the chlorine dosage very closely, sometimes exactly, sometimes within a few hundredths part per million. We have checked our dosage in this way for many years with New York City's supplies.

Mr. Enslow has mentioned a paper we published on the reaction of chlorine with albuminoid nitrogen in sewage ("Effect of Chlorine on Nitrogen in Sewage Effluent Treatment," *Water Works Engineering*, p. 1135 (Aug. 3, 1927)). In this paper, through an error on my part, it is stated that the nitrogen values indicated as *total nitrogen* were obtained by the Kjeldahl method. This is an error. That method was used at each stage of the plants up to the filter effluent. The nitrogen in the filter effluent and chlorinated effluent was determined by the albuminoid ammonia method in order to have comparison between these effluents and our other water supplies. In that paper it is shown that year after year, following the use of liquid chlorine, the chlorinated effluents show a loss of nitrogen corresponding to the reaction:

$$3Cl_2 + 2NH_3 = N_2 + 6HCl$$

That is, the chlorine removes the hydrogen from the ammonia, setting free nitrogen gas. The formula results in the loss of two parts by weight of nitrogen for fifteen parts by weight of chlorine.

Loss of nitrogen, even without chlorination, is generally found, as shown in a paper which we published in 1916 ("Mt. Kisco Sewage Disposal Plant," *Jour. Am. Water Works Assoc.*, p. 908 (December, 1916)). In the septic tank 70 per cent of the nitrogen was lost, probably largely as a gas, indicating that septic action was a more important function in the destruction of nitrogenous matter than of carbonaceous matter. This loss of nitrogen was also noted in the sand filters. (Note Table 2 in that

paper.) This loss of nitrogen may be due to bacterial oxidation of the hydrogen.

Returning to the action of chlorine on free ammonia and albuminoid ammonia, the latter consists of amido and imido combinations with the carbon of organic matter, *i. e.*, $—NH_2$ and $=NH$. These latter when set free probably become ammonia, with the consequent reaction with chlorine indicated above.

The above reaction must take place before chloramine can form, with the latter product an equal additional amount of chlorine taking the place of the hydrogen. Recently considerable work has been published indicating that whether mono-chloramine, di-chloramine, or tri-chloramine is formed depends upon the pH of the solutions. As a matter of fact alkalinity favors or is necessary for the formation of mono-chloramine. When bleach was used at the Mt. Kisco plant there was no loss of nitrogen, such as has occurred regularly with the use of liquid chlorine. The simplest way to my mind to explain the formation of mono-chloramine with bleach and ammonia is to consider that the reaction results in formation of ammonium hypochlorite, NH_4OCl. Take water (H_2O) from this and you have NH_2Cl. The calcium hydrate, formed as the other product, combines with carbonic acid, usually present, to form calcium carbonate.

The reaction of chlorine with ammonia is similar to the reaction with hydrogen sulphide. It is well known that Mr. Enslow advised its use to destroy hydrogen sulphide and resulting odor by prechlorination of sewage in California. Similarly, it has been used to prevent sewage odors by treatment of the gases of sewage. As the odor is chiefly due to hydrogen sulphide, the chlorine is efficient. Chlorine destroys hydrogen sulphide by combining with the hydrogen to form hydrochloric acid (neutralized by the alkalinity present) and precipitates sulphur, which is not noticed on account of its small amount. We have advised and used chlorination with success to destroy hydrogen sulphide present in small amounts in certain deep well waters in Flatbush. Recently in one of these wells, in which free ammonia was present to the extent of 3.5 to 5.5 p. p. m., apparently the ammonia reacted first with the chlorine to form chloramine, probably due to the large excess of ammonia, so that it took a dose of 1.2 p. p. m. with 0.6 p. p. m. residual chlorine before the hydrogen sulphide was destroyed. Not only was the reaction with hydrogen sulphide delayed but also the color developed by the residual with orthotolidin required one-half hour to reach full development. This experience would indicate that at least under some circumstances the chlorine preferred ammonia even to hydrogen sulphide.

It may be that a large part of the nitrogen values we obtain in sewage analyses are not merely in solution but consist of the bodies of the bacteria themselves. This may be indicated, as shown in the Mt. Kisco

paper cited, by the fact that bacteria and *B. coli* were removed at different stages of purification proportionate to the chemical and physical determinations. The rapid reaction of chlorine with ammonia or amido and imido combinations within the bacteria may explain the rapid bactericidal effect which takes place before chlorine absorption is completed. For about nine months, March, 1929, to March, 1930, *i. e.*, during this period, we chlorinated the septic tank effluent at Mt. Kisco with the idea of destroying anaerobes and helping aerobic action in the contact beds. The chlorine dose averaged 7 p. p. m., ranging from 3 to 12 p. p. m. This was not sufficient to maintain continuously even a small residual chlorine. Although evidently not saturated with chlorine, the bacteria and *B. coli* were frequently almost completely destroyed, and this effect sometimes persisted to a considerable extent through the sedimentation basins and sand filters. Although we did not obtain the increased nitrification and benefit we expected, the above results were strikingly interesting.

There is one other point in connection with reduction of B. O. D. which I should like to mention. In the paper previously cited on the Mt. Kisco Sewage Disposal Plant, it was shown that although practically very little reduction took place in the chemical analyses through the contact beds and the secondary settling basin, yet stabilization was accomplished to a large extent, the decrease in oxygen demand being about equal to that accomplished by the septic tank. Similar to this effect, it may be that chlorine destruction of amino bodies may result in such a change that the ability to feed bacteria is destroyed. Stabilization might thus be produced out of proportion to the total absorptive capacity for chlorine.

Sewage Works Operation

Activated-Sludge Plant with Brush Aeration*

By G. M. Ridenour and I. G. Lacy
Research Engineer, Dept. Sewage Research, and
Asst. Chemist, Dept. Sewage Research

Mechanical aeration of sewage in the activated-sludge process by means of brushes was instigated in Holland by Kessener. This method of aeration was first applied to slaughterhouse wastes of strong biochemical oxygen demand, with very good results.[1] However, the period of aeration in this case was approximately 24 hours. Later Kessener applied the same type of aeration to domestic sewages of the cities of Hilversum, Knocke and Breda, with equally good results under shorter periods of aeration.[2]

This paper comprises a discussion of the design, mechanical features and partial operating results of what is believed to be the first activated-sludge plant in this country following the scheme of Kessener on weaker sewages and with detention periods more nearly comparable to those used in other types of aeration in this country.

Description of Plant

The plant under discussion was installed for one of the state hospitals in New Jersey and placed in operation in April, 1931.

The units preceding the aeration tanks consist of coarse screens and preliminary settling tanks. The activated sludge is digested in a separate sludge-digestion tank in combination with the settled solids. Digested sludge is dried on conventional sand drying beds.

The preliminary settling tank is of ordinary hopper-bottom construction, with provision for daily removal of fresh solids to the sludge digestion tank. On the basis of the designed flow the detention period in this tank is $1^1/_2$ hours.

The sludge-digestion tank is circular, with cone-shaped hopper bottom, and equipped with a Downes floating cover. Outlet pipes for supernatant liquor and sludge circulation are provided at points just below the normal surface level in the tank and midway of the depth of the tank. The tank is designed for 3.75 cu. ft. per capita. Gas is collected for heating the buildings.

* *Journal Series of the N. J. Agricultural Experiment Station, New Brunswick, N. J., Dept. Sewage Research.*

The aeration tank, shown in cross-section in Figure 1, is 15 ft. wide and 16 ft. deep, with circular bottom. This tank is divided into two equal sections, each of one-half the full plant capacity. Aeration is provided by brushes similar in appearance to street cleaner brushes. The bristles are of selected piasava weed. The direction of rotation of these brushes is such as to tend to throw the sewage across the surface to the opposite side of the tank. To assist in the rotation of the sewage, submerged paddles are installed in the tank which rotate in a direction that will promote the motion imparted by the brushes. The aeration tanks were designed for a total detention period of 6 hours. A 5-hp. motor drives the brushes and a 2-hp. motor propels the paddles. The motive power is transferred from the

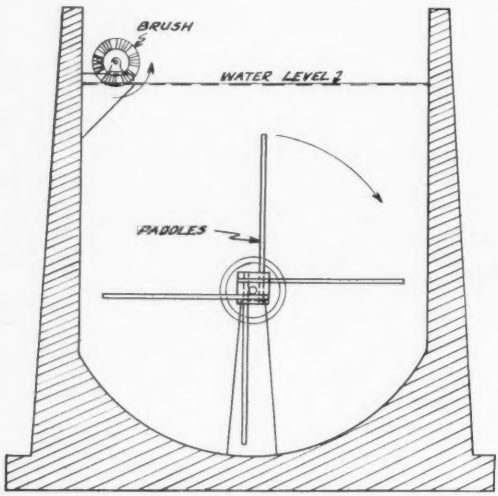


FIG. 1.—Cross-Sectional Sketch of Aerator.

motors to the drive shaft by means of reduction gearing and drive chains. Rheostats are installed for each motor so that the speed may be varied at will. These rheostats permit the brushes to be driven at various speeds between 22 and 84 rev. per min. and the paddles at speeds between 3 and 7 r. p. m. Adjustable weirs are provided on the effluent end of the aeration tank so that the amount by which the brushes dip in the sewage may be varied from 0 to 3 inches.

The final settling tank following the aeration tank is of the plain settling, hopper bottomed type. Designed detention period is 2 hours. Sludge pipes lead from each of the four hoppers to a central well, from which sludge is removed by means of an air-lift pump to the sludge-return channel.

Gate valves are provided on each of these sludge pipes so that the amount of sludge flowing from each of the sumps to the central well may be controlled and varied as desired. Activated sludge is returned to the influent and of the aeration unit through a sludge return channel. The return sludge is measured by a weir on this return sludge channel. Provision has also been made to waste excess activated sludge to the primary settling tank or direct to the sludge digestion tank.

Sludge beds are designed on a basis of 1.0 sq. ft. per capita.

General Mechanical Operating Features of Aeration Tank

Under the usual conditions of operation the brushes in the aeration tank are run at a speed of 60 r. p. m. The depth of submergence of brush bristles in the sewage under average flow conditions is approximately $1^1/_4$ inch.

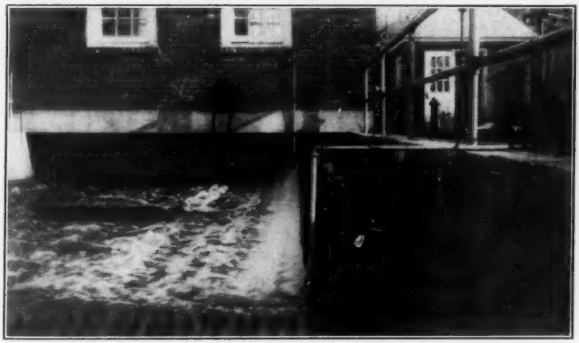


FIG. 2.—View of Aerator Brushes in Action and Tank Surface.

This condition of operation of the brushes raises the sewage from the surface and throws it in finely divided state a short distance across the surface toward the opposite side of the tank. Figures 2 and 3 show the brushes in action under the normal conditions of operation just described. Figure 2 is a view of the brushes and one aeration tank surface. Figure 3 shows a close-up view of the brush.

The paddle wheels normally operate at 5 r. p. m. While the paddles were installed for the purpose of promoting the circulation of the tank contents, and to maintain sufficient circulation velocity in the tank to prevent settling of suspended solids, it has been found that the necessary velocity to prevent such deposition can be maintained by the brushes alone at normal operating speeds without the aid of the paddles. In fact the best results that have been obtained from the plant were during a period when the paddles were completely stopped for adjustment. The surface velocity of the aeration

tank at different speeds of the brushes is shown in Figure 4. While it cannot be assumed that this same velocity is maintained throughout the tank, it has been proven that the velocity on the bottom under all of the speeds shown is sufficient to prevent deposition of the suspended solids. The evidence for this was obtained when one of the tanks was drained for adjustment of the paddle wheels, immediately following a period when the brushes had been running at 48 r. p. m.

Power Consumption and Surface Velocities

The power consumption of the brushes at different speeds is also shown in Figure 4. The values were determined by actual measurement.

It is interesting to note in this figure that relation between the power consumption, speed of brushes and surface velocity. The surface velocity

FIG. 3.—Close-Up View of Brushes in Action.

increases in almost direct proportion to both the speed of the brushes and power consumption, up to a velocity of 4.5 feet per second, where the direct proportion ceases and the curve tapers off. As far as surface velocity and circulation of tank contents is concerned the economical speed of the brushes appears to be approximately 68 r. p. m. Beyond that point increased speed of the brushes is of much less value. This appears to be in accordance with certain fundamental laws of hydraulics.

Work is being conducted on this phase of the plant studies and will be published at a later date, together with an investigation of the relation of surface velocities to velocities throughout the entire tank cross-section.

The curve for power consumption in Figure 4 is on the basis of the actual power consumption at this plant. For the purpose of convenience, power consumption curves are plotted in Figure 5 showing the hp. required per

million gallons of sewage treated on the basis of a 6-hour detention period and with various percentages of sludge return flow.

For this plant it has been found that a 5 per cent return sludge flow is sufficient to maintain the required amount of suspended solids in the aeration tank for good results. However, this will vary for different sewages.

Since the power consumption per million gallons of sewage will also vary with the cross-sectional area used for the aeration tank, the curve for power consumption per foot length of brush is given in Figure 6. All of these power consumption curves are based upon $1^1/_4$-inch submergence of the brushes.

Sewage Flows

Sewage flow from institutions has specific characteristics in the erratic and abrupt fluctuations of rates of flow during the day time and in the

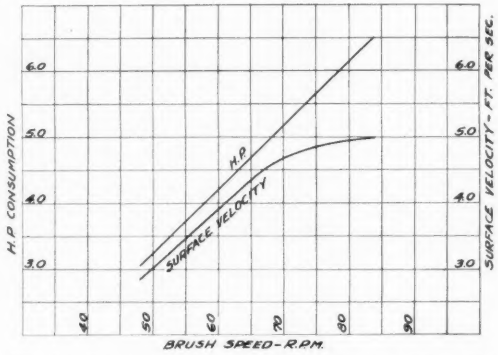


FIG. 4.—Horsepower Consumption Curve of Brush and Surface Velocity.

extremely low flow rates during the night period. Figure 7 shows a typical flow chart from this institution. This chart and subsequent sewage flow analysis is given for later reference in this article as a factor affecting the plant operation and design.

The average sewage flow on the particular day shown was 178 gal. per capita. The maximum rate of flow encountered during the day was 500 g. p. c. and the minimum 35 g. p. c. During a 10-hour period of the 24 hours, occurring during the day time, the average maximum rate of flow was 445 g. p. c. and the average minimum rate during this same period was 250 g. p. c. The rate of flow during this 10-hour period varies continuously between these maximum and minimum limits. The average rate of flow during this maximum day rate was 327 g. p. c. Seventy per cent of the entire total daily sewage flow occurs during this 10-hour period. Figure 7

shows the distribution of the sewage flow over the 24-hour period with maximum, minimum and average flows.

The extremely variable rate in sewage flow at the plant has a very material effect upon the plant operation and design as will be shown in an article to be published at a later date.

Raw Sewage Analysis

The analysis of the raw sewage reaching the plant is shown in Table I. This analysis is of a composite sample collected at half-hourly intervals throughout the day.

TABLE I

ANALYSIS OF RAW SEWAGE

pH	7.8	Dissolved Oxygen	1.0 p. p. m
Suspended Solids	156 p. p. m.	B. O. D. (5 day)	235 p. p. m
Settleable Solids	3.5 cc. per liter	Total Acidity	0.5 p. p. m
Total Solids	580 p. p. m.	Total Alkalinity as $CaCO_3$	130.0 p. p. m
Ether Soluble Material	43.3 p. p. m.	Chlorides	21.0 p. p. m

The analysis indicates that the sewage is comparable in strength, as measured by the bio-chemical demand and total suspended solids, to a normal domestic sewage without industrial wastes. Settleable solids are lower than usually encountered in domestic sewage and the pH is considerably higher. This high pH is due to the high concentration of laundry wastes from the institution. The presence of this laundry waste is also reflected in the low acidity of the sewage. Ether soluble substances are no higher than usually found in domestic sewages. The sewage reaching the plant is fresh, as indicated by the residual dissolved oxygen content.

Sewage Entering Aeration Tank

The sewage entering the aeration tank is of different character due to the passage through the primary settling tank. Whereas the original raw sewage showed an alkaline reaction, the settled sewage entering the aeration tank was about neutral. Residual dissolved oxygen is absent.

The analysis of the settled sewage entering the aeration tanks is shown in Table II.

TABLE II

ANALYSIS OF SEWAGE ENTERING THE AERATION TANK

pH	6.9	B. O. D.	185 p. p. m.
Suspended Solids	94 p. p. m.	Total Acidity	13.0 p. p. m.
Settleable Solids	0.3 cc. per liter	Alkalinity	100.0 p. p. m.
Total Solids	456 p. p. m.	Chlorides	21.0 p. p. m.
Dissolved Oxygen	0.0 p. p. m.		

General Plant Results

Since this article is to be followed by subsequent ones dealing with more detailed accounts of results of investigations at the plant, general results only will be given at this time, without reference to special studies that were made during the following periods.

TABLE III

AVERAGE PLANT RESULTS FOR TWO PERIODS

Unit	Detention Period on Basis of Hours 24-hour Av. Flow	10-hour Max. Flow Av.	10-hour Av. Max. Flow	B. O. D. 5-Day P.p.m.	% Red	Susp. Solids P.p.m.	% Red	Settleable Solids Cc. per Liter	% Red	Turbidity, P.p.m.	Relative Stability, Days	D. O., P.p.m.	pH
First Period													
Screened Infl.				235		160		4.1					7.4
Primary Settling Tank Effluent	5.2	2.5	3.5	190	19.1	85	47	0.13	97				6.9
Aeration Tank	4.4*	3.0	3.6										7.3
Final Settling Tank Effluent	2.8	2.0	2.4	6	97.5	8	96	0	100	5.2	20	2.5	7.3
Second Period													
Screened Infl.				235		160		7.0					7.3
Primary Settling Tank Effluent	2.4	1.2	1.7	185	21.3	94	41	0.5	93				6.9
Aeration Tank	6.3*	3.8	4.9										7.3
Final Settling Tank Effluent	2.1	1.2	1.6	30	87.5	37	77	0	100	9	2	2.0	7.3

Results shown in Table III have been compiled for two different periods. During the first period the sewage flow was low and all plant units were over capacity, with the exception of the aeration unit, which was under capacity at that time due to the use of only one of the aeration units. The other unit was out of use during the entire period to permit adjustment of the paddles as mentioned before. The second period represents the plant re-

* Note—see text.

sults at a later date, when the sewage flow had more than doubled. However, the aeration time during this second period was slightly longer than during the first because both of the aeration units were in service, whereas only one was being used previously. The detention period of the other units however, was considerably less.

The analyses shown in Table III are from periods when the best results were obtained and do not include periods when less efficiency was secured due to mechanical operating troubles not connected with the fundamental process of treatment. However, the results are over a sufficiently long period to indicate definitely the ability of the plant to produce consis-

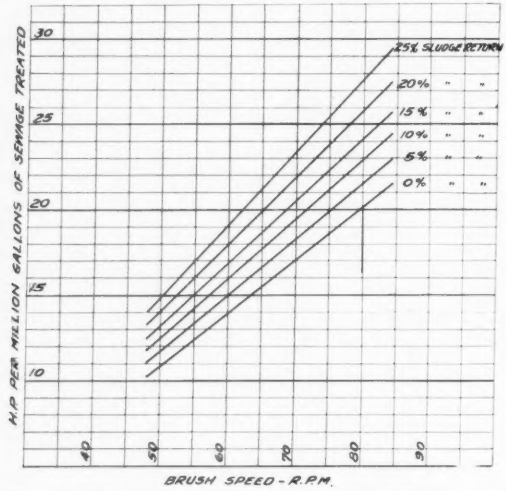


FIG. 5.—Horsepower Consumed per Foot Length of Brush, Submergence $1^1/_4$ Inches.

tently similar results if operation is maintained under the conditions prevailing at these times.

Conditions of Operation during First Period

During the first period the brushes were maintained at a speed of 60 r. p. m. The paddles were not in operation during this period. Suspended solids in the aeration tank averaged 703 p. p. m. Settleable solids in the aeration tank ($^1/_2$ hr.) were 343 cc. per liter. This represents a ratio of weight to volume of solids of 2.05. The varying characteristic of this ratio and its effect will be discussed in further detail later.

Conditions of Operation during Second Period

The conditions of operation during the second period were as follows: brush speed, 64 r. p. m.; suspended solids in aeration tank, 750 p. p. m.; settleable solids in $^1/_2$ hour settling time, 180 cc. per liter; ratio of weight to volume of 4.1.

Discussion of Results

Table III is self-explanatory as far as plant results and efficiencies of the different units are concerned during the two periods.

There are, however, a few points which warrant interpretation and discussion.

The detention period given in the table for each unit is the calculated

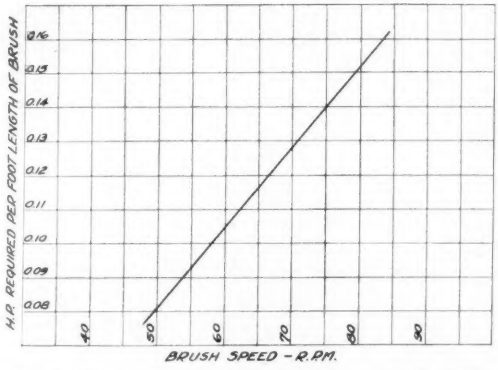


FIG. 6.—Power Consumption of Brushes on Basis of Hp. per Million Gallons.

time of retention of the sewage in that unit, under the different flow rates prevailing over the 24-hour period. The length of time a given amount of sewage is held in the aeration tank varies inversely with the volume of return sludge carried. During the second period a much smaller volume of return sludge was carried. This has been compensated for in the calculation. The detention period given for the aerator in all cases is the calculated time of contact of the sewage with the activated-sludge floc.

Since the maximum and minimum flow rates vary so far from the average at this plant, the detention periods are given on the basis of 24-hour average flow rate, a continuous 10-hour period of maximum flow rate and the average flow rate during the 10-hour maximum flow rate period.

As previously stated, the shorter detention time during the first period, even though the flow was a little less than one-half as great as during the

second period, was because only one of the aeration tanks was being used. In addition to this, a greater return sludge flow was carried during the earlier period.

It is interesting to note that while the best results were obtained during the first period with smaller flow rates, the aeration time during this period on the basis of either average or maximum flows was considerably less than that of the second period. However, this apparent conflict is not due to the differences in time of aeration or in the condition of the activated-sludge floc under these two different conditions. It will be noted that while the detention time in the final settling tank during the first period under maximum flow conditions was 2.0 hours, the detention time in this same tank during the second period under the maximum flow period was only 1.2

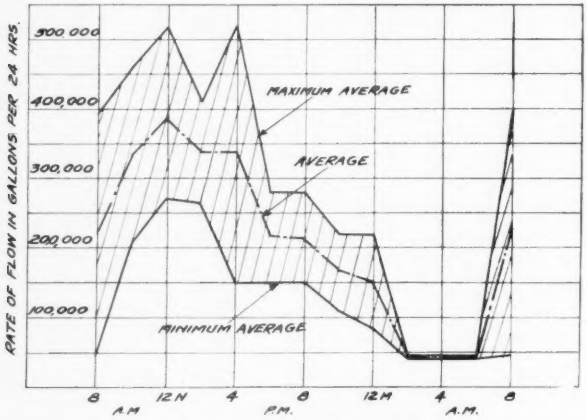


FIG. 7.—Typical Sewage Flow Chart.

hours. This reduced detention time during the second period caused part of the lighter floc to be carried over the final settling tank effluent weir, during the maximum flow rate period. That the reduced detention time was the factor in the difference in results is borne out by the similarity between settling characteristics of the sludge floc during the two periods.

It has been found that a theoretical detention time in the final settling tank of at least two hours is necessary to settle out the activated-sludge floc produced at this plant under average operating conditions and with the aeration times shown in the table.

This is longer than is usually considered necessary, but a study of the average settling curves in Figure 8 will show that while the solids concentrated to approximately 20 per cent of the original volume in 30 minutes, the rate of concentration was much more uniform than encountered in other

activated sludges. It is believed, however, that this latter difference in settling rates is due to two factors, namely, differences in sewages and the very short detention period during ten hours of the day, rather than any difference in the mechanical processes of treatment.

Experiences at this plant indicate that longer aeration periods than shown are not as important to the biological processes of purification as to

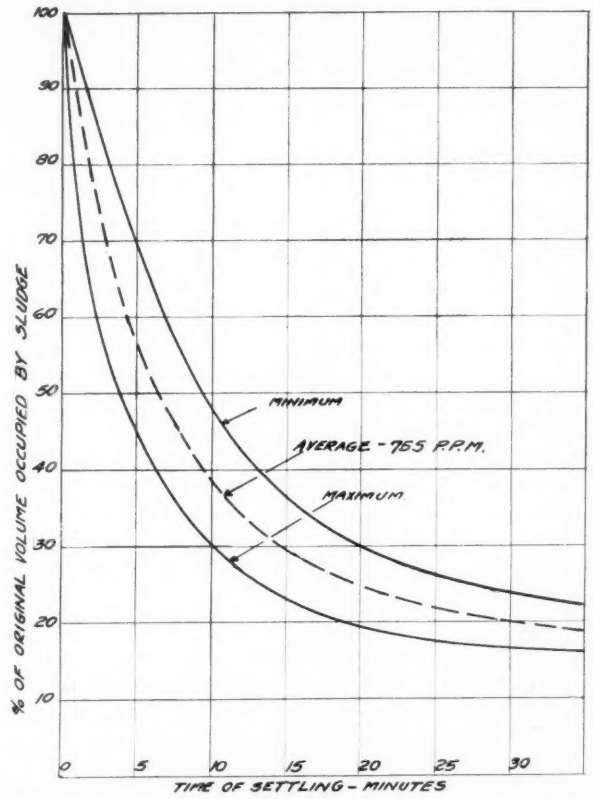


FIG. 8.—Characteristic Settling Time of Activated-Sludge Floc Produced at Hillsdale Plant.

the settleability of the floc, for purification during both periods was continuously very complete, provided the activated-sludge floc was given two hours in which to settle out. In addition to this evidence, special investigations which have been run on the plant show that reduction in B. O. D. and suspended solids was very great under very short periods of detention.

Rejuvenation of the settled activated-sludge floc may of course be an important factor under these conditions and may quite possibly occur at this plant under the existing sewage flow conditions.

Summary

This article is a description of an activated-sludge plant employing brushes and paddle wheels as a means of mechanical aeration. Partial operating results with respect to unit efficiencies are given for two periods of operation, namely, during plant underload and during plant overload. Mechanical operating data are given with special reference to the power consumption of the brushes on the basis of hp. per million gallons of sewage treated and per foot length of brush.

Power consumption for aeration purposes at this plant is 17.5 hp. per million gallons of sewage treated.

The brushes will give sufficient circulation velocity in the aeration tanks to prevent deposition of solids, without the aid of the paddles.

Analytical results show that very good purification was obtained even with short periods of aeration. Comparison of two periods of high and low flow show that while the purification processes in the aeration tank were approximately the same for each period, during the high flow periods the over-all plant efficiency was considerably reduced on account of insufficient settling capacity in the final settling tank.

Raw sewage analyses are given and a characteristic flow chart is shown to explain the difference in plant results during the two periods, by comparison of detention periods in the various units during different periods during the day.

A theoretical detention period of at least 2 hours in the final tank was found necessary for efficient settling of the floc formed at this plant. Characteristic settling curves show that the rate of concentration of this floc is somewhat less than results published from other plants. The reason for this difference is believed to be due to the difference in the sewage treated and the shorter detention period of the aeration tanks, rather than any difference in the mechanical methods of aeration.

References

[1] W. Rudolfs and H. Kessener, "Treatment of Slaughterhouse Wastes in Holland," *Public Works* **59,** 151–154 (April, 1928).

[2] W. Rudolfs, "Sewage Treatment Abroad," *Public Works* **59,** 265 (July and August, 1928).

Symposium on Sludge Handling *
Removal of Raw Sludge from Settling Tanks

BY R. S. RANKIN

The Dorr Company, Inc., New York City

Removal of raw sludge from primary sedimentation tanks in a plant with separate-digestion units should be done in accordance with certain principles, as follows:

1. The sludge must be removed before it becomes septic and rises to the surface of the settling tanks.
2. The sludge must be removed substantially in accordance with the rate of deposition of the solids.
3. The sludge should be removed at frequent intervals and in small volumes so as not to disturb the digestion tank into which it is placed.
4. The sludge should be removed with as little excess water as possible to avoid subsequent handling of this water.

To comply with all of these requirements calls for a study of each particular plant, which means that an operator should first study his problem, usually by cutting and trying to evolve a pumping schedule that best suits his particular needs. To illustrate concretely how this is worked out, an example of the pumping schedule at a plant in the Central West during an extensive test period is given.

Average flow of sewage, 5.6 m. g. d.
Tributary population, 43,000.
Suspended solids removed, 3440 lb. per day, dry basis.
Suspended solids removed, 0.08 lb. per capita per day.
Average moisture content raw sludge, 92 per cent.
Volume of sludge (sp. gr. = 1.025), 5000 gal. per day.
Capacity of pump (by test), 38 g. p. m.
Required pumping period 132 min. per day.
Actual total pumping time, 150 min. per day.
No. of pumping periods, 6 per day.

There are three clarifiers and each unit was pumped for 8 minutes six times a day. Samples of sludge are taken in the middle of each pumping period and just before stopping the pumping from each unit. Operators are instructed at all times to observe the samples withdrawn and if they appear too thin, to cease pumping, allow a sample to stand 15 minutes and if about 50 per cent by volume is water, no more should be pumped; if less water is present, pumping should be continued until proper condi-

* *Presented at the Fourth Annual Meeting of the New York State Sewage Works Association, New York City, January 19, 1932.*

tions are obtained. Operators quickly learn by inspection when to stop pumping.

Frequent pumping at low rates assures a more homogeneous sludge, less excess water and no tendency to create a funnel to draw in overlying sewage. There is no evidence that these low velocities of homogeneous sludge in pipe lines produce clogging, in fact a high velocity often causes segregation of materials and stranding of solids in the pipe lines after the liquid has been drawn off.

Pumping sludge into a digester at high rates, say over 100 gallons per minute, has a tendency to stir up the contents of the digestion unit and to produce an undesirable overflow, high in suspended solids. In heated digesters this also results in waste of heat. With lower rates the overflow is not so disturbed and consequently it is lower in solids content. High rates of pumpage into a digester also disturb gas production and produce fluctuations in the gas supply. Such occurrences are eliminated by lower pumping rates of from 20 to 40 gallons per minute.

Gravity withdrawal of sludge, as practiced in Imhoff tanks, is an unsatisfactory method to use in withdrawing raw sludge from shallow settling tanks because raw sludge tends to segregate and there is not the large volume of sludge to draw on before reaching the overlying water. Usually, the valve in the pipe must be opened wide to start the flow and a rapid rush of sludge results. Before the valve can be throttled water has broken through or else the partially closed valve becomes clogged and must be re-opened with the same action repeated.

Removal of raw sludge of from 7 to 10 per cent solids may best be obtained by a definite pumping schedule based on actual plant tests, using a low rate of withdrawal and as frequent pumpage as plant operating practice will permit. This may mean anywhere from 30 minutes twice a day up to 15 minutes every hour, depending on local conditions and size of plant.

Sludge Digestion and Gas Collection *

BY WESTON GAVETT

With Clyde Potts, 30 Church Street, New York City

Collection of gas from digesting sludge is justified as a means of preventing odor, if for no other reason. The collected gas may be used as a fuel to keep digestion tanks at optimum temperature. Where power is used at the plant, engines may be operated on the gas, either directly connected to the pump or blower or connected to a generator. The size and type of power units are governed by the particular conditions at each plant, such as reliability of local power supply, power rate, population served and probable growth. In using the gas for power much of the heat may be conserved and used for heating digestion tanks.

The operators of the Rockville Centre Plant (see THIS JOURNAL, p. 615 (Oct., 1931)), are still obtaining continuously good results on operating gas engines. At least 15 to 20 hp. per million gallons should be obtained. Goudey reports 36 hp. per million gallons, or sufficient to operate generators to run the plant at the experimental Los Angeles sewage reclamation plant, with a gas production of 1.25 cubic feet per capita.

The disposition of the supernatant liquor or liquid displaced from the digestion tanks is a problem, where this liquor must be returned to an activated-sludge plant. This has been accomplished by the return of the liquor at a low rate to settling tanks preceding aeration tanks, as previously described. Where possible it is safer to keep this liquor entirely out of aeration tanks by separate treatment. Still better is its complete elimination by concentrating sludge before digestion, as described by Gould, Goudey and Rawn.

The use of heated tanks for maintaining a temperature of around 80° F. is now common practice, and a further jump to the thermophilic range of 120° to 140° F. seems to be the next step. The work of Heukelekian and Rudolfs shows a reduction in digestion time to 48 hours with increased gas production. Tests on the thermophilic digestion of distillery wastes recently described by Boroff and Buswell demonstrate that beer slop waste, a material most difficult of treatment by usual processes, was digested in two to six days, producing a stable, inoffensive sludge and a liquor that could be discharged to sewers. It was further shown that gas production made the process appear to be profitable, giving gas at a lower cost than natural gas.

The use of thermophilic temperatures introduces design problems somewhat different than those encountered at the lower temperatures. The

* *Presented at the Fourth Annual Meeting of the New York State Sewage Works Association, New York City, January 19, 1932.*

question has been raised as to whether additional heat required will make the process uneconomical. As pointed out by Rudolfs, the total gas production is no less than at lower temperatures and the reduction in time of digestion and size of tanks more than offset the additional heat needed. In a study of the heat required for an actual design for 80,000 people, the writer found that gas produced would more than suffice for heat requirements. In this design fresh sludge was to be lifted to sludge storage tanks and then through a heat exchanger or preheater to digestion tanks heated by hot water circulated under a false bottom and then to storage tank for digested sludge. Digestion units were to have capacity of 0.2 cu. ft. per capita, and the two storage tanks 0.15 cu. ft. per capita, giving a total of 0.35 cu. ft. per capita. Assuming 0.04 cu. ft. per capita of fresh sludge at 40° F. heated to 120 degrees, and air temperature 30° F., approximately 0.4 cu. ft. of gas per day was estimated as required to heat sludge and make up heat losses, a figure comparable to 80 degree digestion. Design of thermophilic tanks will require special study. Factors to be considered have been indicated by Rudolfs. In general, a compact design reducing the amount of connecting piping, special attention to insulation, method of heating and provision for frequent and continuous addition of solids are indicated.

During the construction of additions to the Morristown sewage treatment works last summer, one of the digestion units was equipped for high temperature digestion. This unit will take sludge from preliminary settling tanks and excess activated sludge from a plant serving 15,000 people.

Sewage Sludge as Fertilizer*

BY JOHN F. SKINNER

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The City of Rochester has four Imhoff plants in operation, from three of which well-digested sludge is drawn by gravity. Although there is ample drying bed area at the BRIGHTON plant, the sludge is lagooned in an isolated spot to save the cost of handling. A relatively small amount of sludge is obtained from the CHARLOTTE plant. Upon removal from the beds, it is piled along the roadside in front of the plant, from which it is soon removed by individuals to whom it is given for use on their gardens, shrubs and lawns. From the IRONDEQUOIT, or main plant, during the year 1931, 38,624 cu. yd. was drawn, of which 13,424 cu. yd. was lagooned and 25,200 cu. yd. was dried on the beds. Ten inches depth of liquid sludge, averaging 93.7 per cent moisture, drained to a cake about three inches thick, with moisture from 50 to 55 per cent. Due to the depth of the tanks, the gas in the sludge as drawn is under about two atmospheres pressure. When this liquid sludge flows upon the beds the gas bubbles can be visualized as having doubled in size, and this idea is further supported by the porous structure of the sludge cake.

The sludge cake when removed and measured in loose bulk in cars amounted to 7032 cu. yd. No attempt has been made to harmonize these figures, for the amount drawn was measured by displacement in the tank, where the location of the surface of the sludge is somewhat uncertain, and there is some loss of water through the bed before the sludge has filled to the 10-inch mark. Furthermore, the measuring of the final cake in loose broken bulk and the variation in moisture of the cake from exposed or shaded parts of the bed, together with the fact that a ponderable quantity of sand from the bed adheres to the cake, make for inaccuracy.

The narrow gauge Kopple cars used contain about two cu. yd. when heaped up and the contents weigh about 2300 pounds. The quantities given are from the operator's records.

It has been the practice to run these cars over a loading trestle from which the sludge cake is dumped into trucks and wagons placed by the customer. Surplus material is piled below. In 1931 the dump was entirely cleaned out, since which time two orders for 500 tons each have been received.

The sales during 1931 were as follows:

* *Presented at the Fourth Annual Meeting of the New York State Sewage Works Association, New York City, January 19, 1932.*

450 cars (900 cu. yd.) = 450 tons, @ $0.50			$225.00
784 loads (3 cu. yd. each) shoveled from dump @ $0.50			392.00
Cash Receipts			$617.00
Given to other departments		Value if sold	
Monroe County Parks	46 cars	$ 23.00	
Municipal Parks	233 loads	116.50	
Board of Education	1508 tons	754.00	
Other parties	19 cars	9.50	
	8 loads	4.00	
Value if paid for			907.00
Total value of sludge			$1524.00

The sludge is used by orchardists and by park boards, golf clubs, schools, companies and individuals on lawns. It is also used by florists in greenhouses for growing flowers. It is a mild fertilizer which does not burn a crop when over-dosed and it is particularly satisfactory on light, sandy loam.

It contains about 2 per cent nitrogen and a small amount of phosphorus, and due to its fibrous and porous structure, it conserves moisture and thus when crumbled is valuable as humus. It is commonly used as a top dressing. Sludge is found to stimulate leaf and plant growth above ground rather than fruit. In the case of tomato plants, which sprout from the seeds ever present in the sludge, the vines grow luxuriously while the fruit is rather scanty.

Several years ago at the IRONDEQUOIT plant, where the site covers 315 acres, a patch of wheat was planted and up to a certain line the soil was given a top dressing of sludge. Wheat in the sludged section was about 25 per cent higher than in the unfertilized portion and the heads were heavier and fuller.

Twelve years ago, early in the spring, four rows of radishes were planted by the farmer occupying the property next to the IRONDEQUOIT plant. These were covered with glass and grown for four weeks.

Row No. 1 was plain, sandy loam with no fertilizer.
Row No. 2 was treated with sheep manure.
Row No. 3 was treated with Imhoff sludge.
Row No. 4 was treated with sludge from an experimental separate-digestion tank.

The results were as follows:

Row No. 1—Radishes never matured.
Row No. 2—Fair radishes.
Row No. 3—Fine plump, tasty radishes.
Row No. 4—Fine plump, tasty radishes.

At the BRIGHTON plant sludge has been used for fifteen years around

Brighton Plant. Luxuriant Shrubbery Fertilized with Imhoff Sludge.

shrubbery and roses and a wonderful growth has resulted, with a riot of roses.

At the CHARLOTTE plant sludge has been used on the lawn and shrubbery, with good results.

On municipal golf links near the IRONDEQUOIT plant the growth of grass on the fairways has been improved by a top dressing of sludge; and sludge has been successfully mixed with leaves and used for winter cover.

In orchards, 10 tons of sludge per acre is used. This corresponds to about 5 tons, dry basis.

Sludge is used by farmers near the IRONDEQUOIT plant and some of it has been hauled 20 miles away. Most of it is now being hauled 5 to 8 miles.

The suggestion has been made that liquid sludge be hauled in tank wagons and sprayed on the land. Several years ago experiments were reported from Bedford, England, which indicated that 86 per cent more value had been found in liquid than in the resulting dried sludge. For the same value about three times the weight would have to be hauled. Loading and unloading would consist in turning a valve. Sludge could be drawn all winter, Imhoff tanks would not have to be drawn so heavily in the fall and separate digestion tanks might be smaller.

The cost of constructing and, in some cases, glassing over drying beds as well as the expensive process of removing the sludge cake would be saved.

At the EAST ROCHESTER plant, where the tank surface is well above ground, two branches equipped with gate valves are provided on the sludge pipe, one to discharge to the sludge beds and the other high enough to discharge into the top of a tank wagon.

During dry weather the water content of the sludge might be valuable on the land, and the opportunity to draw in the winter, when open beds are out of use and farm labor is most available, apparently has possibilities.

Modern Measures of Efficiency in Water Purification and Sewage Treatment*

BY EMERY J. THERIAULT

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This paper comprises a review of certain phases of studies conducted by the United States Public Health Service at the Cincinnati Laboratory for Stream Pollution Investigations. The discussion will be limited to the laboratory side of problems related to water purification and sewage treatment, with particular reference to measures of the efficiency or of the performance of such plants.

Turning first to the extensive studies of the efficiency of water purification plants conducted by Sanitary Engineer H. W. Streeter, U. S. Public Health Service, it is necessary to conclude that the percentage removal of bacteria or, more specifically, of *B. coli*, is not always a sufficient indication of plant performance if several plants are being compared.[1] Even at the same plant, with varying peak loads of pollution, consideration must be given to the loading of the plant in terms of the bacterial content of the raw water in evaluating the performance of a plant. These studies clearly indicate that, with increasing bacterial loads, there is a tendency to produce effluents of higher and higher bacterial content until a point is reached where the usual coagulation–sedimentation–filtration systems fail to produce a water of acceptable quality without resort to chlorination. With water from the Great Lakes this limit is reached at the more efficient plants when the *B. coli* index reaches a value of about 60, corresponding to 60 *B. coli* in 100 cc. With Ohio River water the somewhat higher limit of 80 *B. coli* per 100 cc. seems to hold.

In passing, it may be remarked that the difference in results obtained in these two localities cannot apparently be accounted for on the basis of the greater turbidity of the Ohio River as compared with the clear raw waters obtained from the Great Lakes. The essential difference appears to be in the relatively high pH value of 7.8 to 8.2 which is encountered in lake waters. On the other hand, the pH value of Ohio River water is somewhere between 6.8 and 7.2. Mr. Streeter has shown that for Ohio River water the efficiency of the alum process is greatest at pH values around 5.5 and that it diminishes rapidly as pH 7 is approached. This phenomenon is apparently connected with an increased efficiency of coagulation and adsorption by alum at relatively low pH values which should evidently be considered in evaluating the performance of a plant.

**Presented before the Eleventh Annual Joint Convention of the North Carolina Section of the American Water Works Association and North Carolina Sewage Works Association, Greensboro, N. C., November 3, 1931.*

With grossly polluted waters, a limit is soon reached where chlorination or even superchlorination becomes necessary, not simply as a factor of safety but rather as an integral part of the purification process. In this case the over-all bacterial reduction accomplished is more nearly a measure of the undoubted effectiveness of chlorine as a sterilizing agent than of plant performance in the usual sense. When the residual chlorine content of the filtered water is held below the usual taste-producing minimum of 0.05 to 0.10 p. p. m., the limiting density of *B. coli* compatible with the production of an effluent meeting the revised Treasury Department standard is about 5000 per 100 cc. with postchlorination and 20,000 per 100 cc. with prechlorination. At still higher bacterial loadings it would be necessary to superchlorinate to remove the bacteria and dechlorinate to reduce the chlorine content of the water to an inoffensive limit.

From the public health view-point and from the view-point of those who are primarily interested in stream pollution it is clear that, with increasing burdens of pollution, there are many water purification plants which, essentially, are chlorination plants instead of filtration plants. The distinction is important and has led to the conclusion that without chlorination a considerable proportion of our water purification plants would fail utterly to deliver a safe drinking water.

In this connection there is a growing recognition of the fact, more particularly in areas recently affected by the drought, that bacterial removal, whether accomplished by coagulation and filtration or by chlorination, is not always a satisfactory index of plant efficiency. Reference is now made to undoubted epidemics of gastrointestinal disturbance which, as shown by Surgeon M. V. Veldee,[2] have occurred in localities where the water is above suspicion from the bacteriological view-point. Similar views are advanced by Tisdale[3] who urges commendable caution in the reclamation of sewage for the purpose of increasing the supply of potable water. Although coming more or less as a shock to those of us who have long been accustomed to regard a water as unquestionably safe when free from bacteria, there now appears to be ample reason to suppose that, under certain conditions at least, it may be necessary to measure plant performance in terms of the removal of toxic substances resulting from the decomposition of fecal and possibly other forms of organic matter.

At the present time it is not possible to state with any degree of definiteness just what these toxic substances may be. In fact, the only indication of their presence, apart from the history of the water, is the undoubted effects which they are capable of producing on the human system. The situation in this respect is somewhat the same as prevailed some 12 years ago in regard to tastes of unknown origin in water supplies. The taste was unquestionably present but it was only as a result of the research work conducted by Donaldson, Fager, Trowbridge, Scott and others (cf. Donald-

son,[4]) that we were definitely able to assign the taste to phenolic wastes from by-product coke ovens. We now know, on the basis of recent studies by the Public Health Service, that sewage also contains large amounts of phenol derived from urine as a normal excretion of the human body. In certain grossly polluted waters it can be reasonably demonstrated that phenolic tastes of sewage origin should be expected, even though industrial wastes are largely absent (cf. Theriault[5]). It is not unreasonable to suppose that the toxic products of human metabolism or of anaerobic decomposition may gain access to the water in a similar manner and, in time, the presence of such substances will no doubt be demonstrated chemically as in the case of phenol.

There is admittedly more of the future than of the past in the general idea which is expressed in the foregoing paragraphs. With the growing pollution of streams, however, and with the necessity in numerous instances for the re-use of the same water for drinking purposes, over and over again, with or without the intervention of sewage treatment, it is not unfair to state that the modern measure of water purification plant performance may very well be the production of a palatable and chemically wholesome water, the bacterial quality of the supply being taken for granted, thanks to chlorination. Even now this high standard is being achieved to some extent through ammoniation and especially through the use of activated carbon, although it remains to be seen whether "carbonization" will be as effective in securing chemical wholesomeness as chlorination has been in assuring bacterial sterility or ammoniation seems to be in eliminating physical deficiencies of taste.

Passing now to sewage treatment, it is perhaps safe to say that with the development of readily applied procedures for determining the oxygen demand of raw sewage and of sewage effluents, and with a clearer understanding of the de-oxygenation process, it is now possible to obtain a fair measure of the performance of any given plant (Theriault[6]). Useful as this information may be, it does not afford any indication of desirable remedial measures in the all-important case when the performance of the plant is poor. If the plant is out of order a satisfactory indication of plant efficiency may be obtained by the readily performed suspended matter or settleable solids determination or else by simple inspection of the effluent.

In studies which are now in progress at our Cincinnati laboratory the whole aim and purpose is to develop tests which will not only serve as indicators of plant performance but which will also convey some idea of the remedy, if any, which should be applied.

With particular reference to the activated-sludge process of sewage treatment, it would seem necessary in evaluating the performance of a plant to consider not only the oxygen demand of the raw sewage and of the effluent, but also the oxygen requirements of the sludge itself. In recent

years several methods have been proposed for determining the oxygen demand of sludge without dilution. Although no one but the man who invented them can be reasonably expected to do much work with these complicated procedures, they are, nevertheless, capable of furnishing information of the highest value.

The values obtained for the oxygen demand of activated sludge are remarkably high and, for sludge drawn from the bottom of clarifier tanks, the oxygen requirements may easily exceed 10 milligrams of oxygen per liter of sludge per minute. As the dissolved oxygen content of water, at best, is only 9 or 10 p. p. m. at ordinary temperatures, it is clear that anaerobic conditions probably prevail at the bottom of all clarifier tanks as now designed.

Another item of importance is the question of reaerating or reactivating the sludge prior to mixing it with the incoming raw sewage, concerning which considerable differences of opinion appear to exist among engineers. From the view-point of the physical chemist, one condition to be satisfied is that the amount of oxygen supplied to the sludge, as dissolved oxygen and not simply as air, shall exceed a figure of, say, 10 milligrams per liter per minute. Unless this is done, the time spent by the sludge in the reaeration tanks will simply be an aggravation of the anaerobic conditions which prevail in the lower part of the clarifier tanks. The sludge will therefore become more septic instead of being reactivated.

Now it would seem a simple matter to determine dissolved oxygen in sludge, and such indeed is the case with the supernatant sludge liquors. When the sludge itself is present, however, it is necessary to conclude that a reasonable degree of accuracy cannot be achieved using the methods which are now available. Until a procedure is developed whereby the dissolved oxygen content of activated sludge can be determined in a few seconds, instead of in a few minutes, there will be considerable uncertainty regarding the sufficiency of the supply of dissolved oxygen, apart from the visual abundance of air blown through the sludge. Problems of under-aeration and of sludge reaeration are so closely related to plant performance that an effort is now being made in our laboratory to develop the desired method of analysis.

There is another class of tests yet to be developed before a fair evaluation of the performance of an activated-sludge plant can be made. In diagnosing such conditions as overloading or in estimating the amount of sludge to be carried in the tanks, it would seem necessary to have some readily applied procedure whereby the clarifying power or the adsorptive capacity of the sludge could be measured with a fair degree of accuracy. Such a method is not now available although preliminary studies have indicated that the development of a test for the quality or condition of activated sludge is by no means an impossibility.

In these necessarily brief remarks, an attempt has been made to convey some idea of the lines of research which are either in progress or in immediate prospect at our Cincinnati laboratory for Stream Pollution Investigations, and to indicate at the same time certain tendencies which are manifest in water purification and in sewage treatment.

Looking ahead to the ever-increasing pollution of streams, the possibility exists that in water purification more importance will be attached in the future to the chemical impurities of water, without in any way detracting from the necessity of eliminating the danger of bacterial infection. Progress in this direction may very well depend on the identification and quantitative measurement of the toxic substances which in certain instances have been presumably responsible for observed outbreaks of intestinal disorders.

In sewage treatment there is a real need for the development of tests which, while yielding information regarding actual plant performance, will also be more informative than the oxygen demand procedures in the indications which they are expected to furnish of desirable remedial measures.

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Financing Sewage Disposal*

BY HOWARD R. GREEN

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There is a growing demand for sewage disposal as a means of eliminating objectionable river pollution. This demand has been productive of extended discussions in various conferences, conventions and press notices during the past year.

Three parties seem to have sprung into being. The first has for its motto "Purity at any price." It includes the most enthusiastic members of conservation and sportsmen's organizations. The second party operates under the slogan "Purity if we can afford it," and includes the great mass of citizens who appreciate the value of decent conditions, but who must be shown that these conditions can be secured at a cost within their means before endorsing the movement. The third party uses as its text "Let the fishermen go to Minnesota." Its members are unalterably opposed to sewage treatment or stream purification, and they use the same line of reasoning that was so popular a few years ago among the opponents of the good roads movement when they kept Iowa in the mud under the banner of "Why build roads for tourists?"

A frank discussion of the points involved is healthy, but if this discussion develops or degenerates into a heated argument, partisans are created, and partisans are more interested in winning the debate than arriving at a logical conclusion. Ample proof of this statement is afforded by the proceedings of any legislative body.

The "Purity at any price" party represents a relatively small group. It labors under the delusion that the clear stream water of a hundred years ago before the prairie sod was turned to cornfields can be returned by some magic touch. They lay great stress on the value of fish life in the streams, whereas fish life should be considered chiefly as an indicator of the condition of the stream. In other words, if pollution is severe enough to exterminate fish life, the water is dangerous for human contact or use. The type of propaganda circulated by the "Purity at any price" group furnishes the opponents of sewage treatment with most of its ammunition: rash statements of enthusiasts are refutable, and are selected by opponents to represent the chief claims of benefit of the advocates of stream purification. Pioneer conditions for the sportsmen cannot be returned. Abundant fish life is desirable, but not economically essential. This phase of the problem is incidental only to the major question of public health.

* *Presented before the Iowa Sewage Treatment Conference, Iowa State College, Ames, Nov. 20, 1931.*

Probably it is safe to say that the great majority of citizens belong to the second class, that is, they would like a reasonable purification of Iowa streams if it is procurable at a reasonable cost. They would like our streams to be returned to a condition not repulsive to sight nor offensive to nostrils; streams safe for recreation, not hazardous to the public health. They would like streams susceptible to use as public water supplies when given reasonable treatment, provided such benefits can be procured at a cost in line with similar demands of a progressive people.

As to the opposition group, much may be said. Their oft-repeated slogan, "Let the fishermen go to Minnesota" is typical of opposition parties. True, stream purification *will* benefit the fishermen just as good roads do benefit the tourists; but who will now say that the benefit to the tourist is any more than a minute incident as compared with the general benefit to the state. Yet, that argument kept us in the mud for years, and a variation of it probably will keep our streams putrid for more years.

The opposition would have you believe that the idea of sewage treatment is new and untried. They neglect to tell that out of 321 Iowa cities and towns having sewer systems, 217 already purify their sewage. They neglect to publish the fact that 64 per cent of the population in second-class cities and towns served by sewer systems is also served by modern treatment works. They neglect to tell you that taxes in these 217 progressive communities compare very favorably with those in cities now so strenuously opposing such a measure as impracticable and prohibitively expensive.

Of course it is too much to expect extreme consistency in the administration of public affairs any more than in our private affairs. Public affairs are conducted by human beings and consistency is not a predominating virtue of the race. Yet, it seems strange that when the protection of the public health demands the presence of an army to enforce the testing of cows for tuberculosis, those same cows are allowed to wade into streams and dangle their udders in the sewage of some nearby town. It seems strange that the state spends vast sums to develop parks exclusively for recreation on streams so unfit for recreation as to be absolutely repulsive. It seems strange that if 217 Iowa cities and towns could afford to build sewage disposal plants a few years ago at the advanced prices of peak periods, when labor was scarce, that other cities cannot now afford to finish the job so far as they are concerned at materially lower prices when labor really needs the chance to work.

Cost of Sewage Disposal Plants.—There is no set rule for estimating the cost of sewage treatment works, which is applicable to all communities. Each city or town constitutes an individual problem. It is safe to say, however, that in the typical moderate-sized town having a population ranging between one and ten thousand and without complications of

industrial or trade waste, sewage treatment works adequate for substantially complete purification can be constructed at the present exceptionally low level of construction costs at from $8.00 to $12.00 per capita, using the actual population of the city as a basis. Larger communities ordinarily have numerous industries and the wastes from these industries must be reduced to an equivalent population basis before a cost estimate can be made. As an example, a meat-packing plant might easily have a population equivalent of 25,000, so far as sewage production is concerned. This population equivalent would have to be added to the actual population of the city in question before the cost of the required plant could be determined. It is obvious that small communities discharging sewage into large rivers do not require as great a degree of purification to avoid nuisance as would the same communities if located on smaller streams. Therefore it is exceptionally dangerous to throw out any general estimate of cost until a study of the actual conditions surrounding any particular case has been made. It is safe to say, however, that the cost of constructing sewage treatment works today is approximately one-half what it was in 1919 and 1920.

Methods of Financing.—The statement has often been made in many cities that the people would like to eliminate gross stream pollution, but that on account of tax and debt limits there is no legal means of financing the project. This statement will not bear inspection in a single case in Iowa. Any city or town can undertake such a project immediately, legally and economically, claims to the contrary notwithstanding. To be sure, it cannot be done without cost, or taxes, but it *can* be done. The laws provided are flexible enough to provide an equitable and moderate method of financing for any city which really wants sewage disposal. Contrary representations originate from sources opposed to sanitary development and stream conservation. The criticisms of the existing statutes are apparently inspired by opposition to the idea of sewage purification, rather than valid objection to the means of financing.

If there is a real need of sewage treatment for any city, the work may be undertaken today, by the city council, on its own motion, without a popular election. If there is no such real need, then the matter should be dropped without further waste of time in debate or discussion.

The statutes of Iowa provide three separate methods of financing the construction and operation of sewage treatment works. The first is by millage levy taxes against all the real and personal property within the city or town. The second is by a special assessment against all benefited property within the city or town. The third is by a system of sewer rentals. Any combination of the three methods may be used by the city council. The aim in financing under any or all of these methods should be to distribute the cost as nearly as possible in proportion to the benefits

received by the individual property owner. Obviously, the system which would be equitable in one community might be unfair in another. In a small community, having no industries, it is probable that a combination of the special assessment and general millage levy taxes should be used, but in a community where industries predominate or become a major factor in the sewage treatment problem, the sewer rental system recommends itself strongly.

Legal Aspects.—Any Iowa city or town may legally construct sewage treatment plants. Such plants in the eyes of the law are considered as a part of the sewer system. They are financed in the same manner as that provided for a sewer system, or the portion of the sewer system constituting mains or interceptors. They may be constructed as a part of and in the same contract with the sewer system, or they may be built later as an addition thereto. Municipalities have the right to establish sewer districts by ordinance. A city may be divided into several such sewer districts, or the entire incorporated area may be included in one. All the territory in a sewer district may be assessed with the cost of constructing sewage treatment works.

Financing by Special Assessment.—The cost of constructing sewage disposal plants may be levied against the various lots, parts of lots or parcels of ground draining to, or susceptible to drainage to, the site of the disposal plant. Such assessment must be in proportion to the benefits to each property and must not, in any case, exceed one-fourth of the fair value of the property in question. These special assessments are payable in the same manner as other municipal improvement costs; that is, in ten annual equal installments, paid at the same time and place as the March 1st installment of ordinary taxes. Any property owner may pay off the unpaid portion of such tax at any time. Interest on the deferred payments must not exceed six per cent. When the work of construction has been completed, the city may authorize and issue special assessment against that lot. The interest on such certificates shall not exceed six per cent. As an alternate method of financing, the city also has the right to consolidate the special assessments and authorize and issue special assessment bonds in amounts which are multiples of $100, but not exceeding $1000. These bonds mature serially in amount equal to the anticipated collection of special assessments each year throughout the ten-year collection period. They are callable on or before the date of maturity, if collections exceed the anticipated annual amount. The interest on such bonds must not exceed five per cent per annum. These bonds are not general obligations of the city as a whole, so far as running against the statutory limit of indebtedness is concerned. In other words, they are not considered a city debt, but are an obligation of the privately owned property assessed, the city merely acting as collector for the bond holder.

A recent Supreme Court decision, however, makes these bonds an actual debt of the city, so far as payment is concerned, on the theory that the city, in issuing the bonds, represents that it has done everything necessary to make the securities good, and failing to do so, must assume the obligation of payment.

If the total of all special assessments levied falls short of the actual cost of construction of treatment works, the city as a whole must pay the difference. This difference may be paid from any available balance in the general fund, the sewer or sewer district fund, the sewer outlet, purifying plant and dump-ground fund, or from sewer rentals. If the available balance in these four funds is insufficient to meet the deficit, a five-mill annual levy against either of the sewer funds may be anticipated over a period of years not exceeding twenty. In anticipation of the collection of these millage levies, bonds against the respective funds may be issued by the council on its own motion at not over five per cent per annum, both interest and principal to be paid from the respective funds. The city may dispose of these bonds at public sale at a price not less than par and use the funds from such sale to pay all or any part of the cost of construction of the treatment works. The total of general obligation bonds so issued shall not exceed, when added to all other general obligation bonds outstanding, the legal limit of indebtedness, which is five per cent of the actual value of taxable property within the city.

Special assessment bonds, special assessment certificates, or general obligation sewer bonds, as outlined above, are issued upon vote of the city council and do not necessitate a bond election.

Sewer Rental Law.—In addition to the special assessment method and millage levy method outlined heretofore, the city council has the right to finance all or any part of the construction and maintenance of sewage treatment works, by the collection of sewer rates or rentals. In this case, funds needed immediately for the construction of treatment works would be secured through the issuance and sale of bonds as in the other two cases; but instead of collecting millage levy taxes against all the real and personal property within the city, or special assessments against each benefited lot or part thereof, the city council would pass an ordinance containing a rate schedule similar to the rate schedules for municipal waterworks, light plant, gas works, or similar utilities. The theory behind this law is that it makes possible the collection of the cost of building and maintaining the treatment works in proportion to the demand made for service by each property.

Inasmuch as sewage is usually defined as the used water supply of a city, it appears that the consumption of water by any property is a very accurate index of the demands made upon the sewage treatment plant by that property, and the benefits from such an installation accruing to

that property. It is therefore apparent that if the quantity of water consumed by a property is used as a gauge and a charge is made for sewage treatment on the basis of that index, the result would be a fee in proportion to the benefits derived.

In other words, when the cost of financing the sewage treatment plant is determined, the ordinance might be so drawn that a percentage would be added to the monthly or quarterly water rentals. This percentage would be collected in the same manner and at the same time and place as the water rentals without the necessity of additional clerical help. This percentage would be turned over to the sewage department to defray interest and principal payments on the original investment, as well as operating expenses. The total of all these percentages would be sufficient to pay the total cost of construction and operation, unless it was determined that a portion of the cost should be paid by millage levy or special assessment.

In the case of properties which have developed their own water supplies and are not consumers from the municipal system, that supply should be metered and a proportional charge made for the quantity of sewage produced. This would apply particularly to industrial plants. Another variation would be in the case of industries producing a very strong sewage, which would materially affect the cost of treatment. The law is elastic in that it allows each city council to determine the rate, methods of collection and other details of operation of the system. The sewer rental law is not new. It has been used with satisfaction in numerous other states. It operates on the same basic theory as any other municipally owned utility; namely, that the charge shall be in proportion to the service demanded by each individual.

The Attorney-General of Iowa has held that in the application of the sewer rental law, any bonds issued in anticipation of the collection of sewer rentals shall not run against the indebtedness limit of the city or town, but shall be similar in effect to special assessment bonds.

Much caustic comment has been directed against this so-called sewer rental law. Briefly summarized, the objections are as follows: "Why charge the property owner rental for the use of a sewer he has already paid for?" The answer is obvious: If the sewer has been paid for, there is no need for additional funds and therefor no rental or any other tax is necessary. The rental is in lieu of millage levy taxes now being collected to retire bonds issued to pay the cost of prior construction. The sewer may have been "paid for" but the bonds, with which the payment was made, are not yet retired. If rentals are used, an equivalent reduction in millage taxes must be made.

"If rentals simply replace millage levy taxes, there is no use in using them, because the total tax is just the same." The total funds collected

are the same regardless of whether rentals or taxes are used. The difference is in the equitable distribution of the cost among all the properties of the city. If the cost is paid by millage or "regular" taxes each property pays in proportion to its assessed value and not in proportion to its production of sewage. The cost of building the sewage disposal plant depends upon its total capacity. Its capacity is the sum total of all the contributors' requirements. Each property should pay for the proportion of this total cost that it makes necessary. As an example, consider a warehouse having the same assessible value as a laundry or creamery. If sewage disposal is paid for by millage taxes, then each will pay the same cost, but the warehouse produces no sewage, while the quantity originating on the other properties runs into thousands of gallons per day.

It seems inequitable to charge a property for sewer service on the basis of its value. If this reasoning is wrong, then let us abolish water rentals and let each property pay for the maintenance of the water works by increased taxes, regardless of the quantity of water consumed by each property. We pay for water piping in our houses, yet we pay "rentals" for the delivery of water through it. Gas and electric services are on the same basis.

It must be remembered that the methods of financing which have been provided by the legislature are optional in each case. There is nothing mandatory about any one of them. If any method does not suit the conditions existing in any city, then that method may be dropped from consideration. It does not have to be used. It is assumed that each city administration will make use of the methods particularly suited to its condition, when and if it sincerely attacks the problem. Millage levies may be applied to cover the portion of cost chargeable to the general benefits to the city at large by reason of improved sanitary conditions. Special assessments or rentals may be applied to the properties directly benefited in industrial cities, where the assessible value of commercial and industrial property is not deemed to be on the same basis as residential property. This would tend to equalize the distribution of cost and decrease the burden on small home properties.

Cost per Capita.—The stumbling block seems to be the total cost of the construction of sewage treatment works in communities of larger population. It is the cost per capita, however, which should be of greatest interest to the taxpayer and his official representative.

Assuming that relatively complete treatment is necessary for a given community, and that $10 per capita will cover the cost of construction of such a plant, it is obvious that so far as dollars and cents are concerned, it makes little difference which method of financing is used, except as to the distribution of the cost among the various properties in a city or town. If the cost is $10 per capita and the project is financed over a period of 20

years, the annual per capita payment on principal would be 50 cents per year. With interest at five per cent per annum, the average interest payment would be 25 cents per capita per year. Depreciation and maintenance, including operating costs, would probably account for 50 cents per capita per year, or a total of $1.25 per capita per year for all charges. This cost might be reduced by extending the principal payments over a longer period of time, but there is ample proof in many Iowa plants that this per capita estimate of cost is conservative, in view of the present low level of construction prices.

Our Past History.—One reason that Iowa taxes are considered burdensome today is because during the flush times of 1919–20–21 the greatest orgy of public construction ever known in the state was embarked upon by school districts, cities and counties at the very highest known level of construction prices. Today, under vastly changed conditions, the taxpayers are meeting the exorbitant construction costs of that period. Is it possible that we have not benefited by that experience? Is it possible that we cannot see that the time to construct public works is during the time of depression in private lines of business, thereby smoothing out the curve of unemployment and labor shortage and materially reducing the average taxes over a period of years. One thing is certain. If sewage treatment plants are necessary and are to be built within a reasonable term of years, the taxes in the cities affected will be much lowered by reason of undertaking those projects today, than by waiting for a more optimistic frame of the public mind. When that optimism arrives, higher prices will arrive with it.

The major point is to determine whether or not sewage treatment is a necessity for any particular city. If it is found that it is necessary, then the logical procedure would seem to be to proceed with construction on the lowest possible cost basis, thereby lowering the general level of taxes and employing labor at a time when such employment is critically needed.

Sewage Treatment and the Public*

BY LINDON J. MURPHY

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A well-known lecturer arrived in a small southern town to give an address. His train was late in getting in so he checked his baggage at the depot, and hired a negro taxi driver to take him direct to the meeting place. The colored driver became inquisitive: "Pardon, Sah! Am you a travelin' man?" "Yes," the lecturer answered, "I travel." The darky asked, "Might ah ask what you all sells?" The lecturer replied: "Wit and wisdom." The driver pondered a moment and then remarked: "You am de fust travelin' man I seed what carries no samples."

The superintendent of sewage treatment or the city official charged with supervision of the municipality's sewerage system has been in the position of the lecturer. He has of necessity been a salesman—but with no samples; nothing attractive or productive to which he could point with pride in winning the support of the city council and the public.

Sewage treatment has been the unwanted step-child among the city departments. The public has not been interested in its "used water supply." Plants well designed in the beginning have been allowed to deteriorate rapidly for want of operating attention and funds. Because sewage works are non-revenue producing, remotely located downstream, and often unpleasant or difficult to approach, councils have ruthlessly cut their budgets.

But times are changing. What has been of interest to only a few city officials is becoming of interest to the general public. Our city and state health departments, the Izaak Walton League, and conservation departments have brought to us the sinister facts concerning the unrestricted discharge of sewage wastes into our watercourses. We have come to realize that with our growing concentration of population it is no longer sufficient merely to carry the wastes of household and industry to a stream.

With more time for recreation, a new interest in the out-of-doors, highways affording easy access to remote locations and cheap transportation for all the family we are learning more about our streams and about the city's handling of its "used water supply." We have been appalled to learn the condition of most of our streams, and of the fact that the health and water supply of families and communities is endangered through our carelessness and neglect.

We have been indignant to learn that our water plant is forced to care for the sewage of cities upstream, before the water is fit for domestic use. We have been surprised to find the stream which wound by the old swim-

* *Presented before the Iowa Sewage Treatment Conference, Iowa State College, Ames, Nov. 20, 1931.*

ming hole turned into a sluggish, vile-smelling sewer. We have been amazed to learn that the contamination from our municipal sewers, from canneries, creameries, packing plants and other industries has so badly polluted several of our Iowa streams as even to destroy fish life.

Four and a half tons of sewage solids per 100 persons per year discharged into our streams is beginning to have a new and sinister meaning. Its relation to the observed conditions of our streams is being brought home to the average citizen.

Sewage Disposal as a Utility

Recent legislation is putting sewage treatment in a new light. The sewer rental law adopted in Iowa by the last legislature puts sewage disposal on a public utility basis. Operation as a utility, rendering service as other utilities, where the individual may pay for disposal of his own share of wastes, will create revenues, and therefore an operating fund that is a direct tax for a direct service. The old budget problem is thereby removed and it becomes possible for the sewage works to stand upon its own feet and finance its own needs.

Operated as a utility the modern sewage treatment plant will no longer be the unwanted step-child of the city. The average citizen will realize through his sewer rental that he is a stockholder in this municipal utility. The plant belongs to him, and he will want to see what kind of service he is getting for his money. The efficient disposal of his refuse represents his dividends. He will want to know what it is all about, and he has every right to be shown.

Sewage treatment plants are becoming a necessity in practically every Iowa community. With the growth of our population and the increasing emphasis upon public health, conditions which were condoned a few years ago can be no longer tolerated. Makeshift plants and haphazard operation are no longer acceptable. The world moves.

How then can the city official, and the sewage works superintendent bring this public utility before the public in such a way that it may be adequately supported and efficiently managed?

Making the Plant Attractive

Several worth-while expedients suggest themselves. First, he can make the plant attractive. Modern methods are helping a great deal. We are realizing that it pays to put a reasonable amount of money into the improvement of the appearance of buildings and grounds.

A number of new sewage treatment plants are close in and favorably situated. The whole plant is made as attractive and popular as the water works—and water works have long been the show places of the community.

The public judges a plant largely by its appearance. While it won't be possible for all of us to secure immediately fine new plants, we can make the most of our present sewage works. Fine lawns are always a possibility because of the sludge available for fertilizer; weeds and grass can be kept down. Shrubbery banked in corners and other advantageous spots adds to the appearance of the plant. Neat flower beds are attractive. Clean-cut driveways and walks invite the visitor to explore the plant. Tools can be kept in order, and apparatus appropriately painted.

Fortunately good plant operation goes hand in hand with cleanliness. Offensive odors coming from the plant advertise the fact that for some reason sewage wastes are not being properly handled. It may be a settling tank in which satisfactory bacterial action has been disrupted by the introduction of unsuitable industrial wastes; it may be a filter bed which has become clogged; the nuisance may be caused by the discharge of unripened sludge onto the sludge beds, or it may be due to a lack of attention or cleanliness about the plant. City water is a real aid in keeping things clean and should be provided at every sewage treatment works.

The plant can be made attractive indoors as well as out. General cleanliness and order will work wonders; good ventilation and freedom from odors can be sought; dust and cobwebs may be held under control; door knobs and frames can be kept clean; a reasonable use may be made of paint and whitewash to improve appearances.

An efficiently operated and attractively maintained plant can be a real asset to the community; it can be a public utility of which the operator, the city official and the public can be justly proud.

Encourage Visitors

A second suggestion to bring the sewage works favorably before the public is to encourage visitors. The plant must first be put into proper operating condition and made attractive; then you are ready to invite Mr. and Mrs. Average Citizen to visit this, their own public utility.

It has often been said that the less a man knows the more he kicks. A person fears and criticizes what he does not understand. Because sewage treatment is here as a permanent necessity it must be adequately supported and financed. The citizen stockholder who really pays the bills must be informed as to the why and wherefore of the plant. His interest must be aroused, his reason satisfied and his approval secured.

It is therefore the part of wisdom to encourage visitation at the plant. A visitor will appreciate the importance and complexity of this utility when he has been courteously received, and given a short but interesting and informative trip about the plant. He will leave with an understanding of its processes, a new appreciation of its problems, and a respect for those charged with its management.

Direct Publicity

A third suggestion for placing the plant favorably in the public eye has to do with even more direct publicity. Get news about the plant to the city officials and to the public.

Your city officials may know but very little about the sewage works. They may not realize the necessity and importance of sewage treatment. They may not know that the work of the plant is fundamentally crucial to the health and well-being of even more people than the population served by the water works. They may not understand to what an extent it preserves the decent self-respect of the community. Tell them about it.

The average city official is interested or should be in the sewage works. It is one of the public utilities with whose supervision he is charged. He really likes to know what is going on. Tell him of your work, your achievements and your problems. If he is acquainted with you and the work and needs of the plant he is much more likely to support you when equipment or improvements are requested.

You may be a friend of the editor of the local paper or may know one of the reporters. They are always looking for news, and may be able to dramatize very effectively the story of the plant, its complex processes and spectacular operating features, the large Sunday group of visitors or the out of town expert who dropped in to inspect the plant.

There is an old saying to the effect that to be out of sight is to be out of mind. This is certainly significant with regard to city departments. That city department which is out of mind is certain to be out of consideration when appropriations are made. And that city department or utility which has most thoroughly sold itself to the City Council and to the public will find its needs most generously provided for.

So we must first bring our sewage works to the highest possible point of efficiency and attractiveness—to the place where we can point to it with pride, and then we must "get our light out from under a bushel." We must encourage visitors and in every way let the city officials and public know that they have, and are part owners in, an important and progressive public utility. Nothing will return such enduring dividends to the sewage works, to the city officials, superintendent and to the community served as will such a program.

Sewer Rental in Pennsylvania*

BY GRANT M. OLEWILER

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In order to understand the adoption of the sewer rental idea in Pennsylvania it is essential to review a small amount of the history of a First Class Township.

In 1899 the Legislature of Pennsylvania passed an act to classify townships according to the density of population, making all townships with a population of over three hundred persons to the square mile first class townships and all others second class townships. Prior to this event townships were ruled by the County Court with local officers called supervisors to execute the wishes of the people and the Court.

Under the new organization the first class townships were to have a commission form of government which would be self ruling, as the purpose of the division was to allow sections which had passed into the class of villages to solve for themselves problems which were entirely local.

As a township with the necessary population, Lower Merion Township became one of the new first class townships and was so organized in 1900. Inasmuch as its experience is typical, a brief summary will be given. One of the most pressing needs was the establishment of a sewer system for the sections which had developed into villages and it was this situation which confronted the commission upon its organization.

The commission had the task of financing the construction, operation and maintenance of a sewer system in the smallest political unit of the state—a unit of such limited income that the annual revenue was largely consumed in the construction and repair of the public roads, even at a time when the demand for good roads was limited to main thoroughfares to connect the various villages.

Police and fire protection had been recognized as necessities and to burden the budget further with the charges for operation, maintenance and interest on bonds, floated to build sewers, pumping stations and treatment works, would mean that the road program would have to be sacrificed if the township were to remain within the limit of the ten mills tax on each dollar of assessed real estate valuation as provided by the Act of Assembly.

It was true that a portion of the construction expense could be recovered from abutting property owners when the sewer was laid in a public road, but where the construction was in a private road or over private property, as in the case of a trunk sewer, the assessment had to be made by a jury of

* *Presented before the Fifth Annual Conference of the Pennsylvania Sewage Works Association, State College, Pa., June 24, 1931.*

view of the county and it was entirely possible that the property owners by setting up damage claims could offset, at least in the minds of the jurors, such benefits to the private property as might be claimed by the local authorities and that the major portion of the expense would fall back upon the township.

Another phase of the problem was that even in the smallest township, by reason of its rural nature, it was unlikely that the entire township could be sewered at one time. To levy upon all properties in the township by adding to the general tax rate the cost of mains, stations and treatment works serving only a portion of the township would result in a privilege granted to a few at the expense of all. This was especially true as the topography was such that the township would be divided into many drainage areas which could not be economically connected because of topographic or political divisions.

Engineers were retained to study the design of a sewer system and at the next session of the legislature the act which provided that properties abutting on sewers could be charged with their due share of the cost of construction and maintenance was amended to provide for the assessment of a monthly or annual charge to all persons connecting with the sewers, in addition to the assessment of such part of the cost of construction as was lawful. This opportunity was seized upon and a sewer rental established.

In the cases of boroughs which were created largely by taking the populous sections of the townships and making of them a separate political body, there were many things which made more logical the paying of charges from the general taxation. (1) As this unit was largely developed before its creation, the entire area had need of a sewer system. (2) The limits of taxation rates were not as low as in the townships. (3) The topography was generally such that there would be few separate drainage areas. (4) By reason of the compact development the number of users per mile would be greater and therefore the cost to the individual owner would become increasingly smaller until the receipt and payment of separate bills would become a matter of annoyance to the taxpayers.

The case of the city is much the same as that of the borough except that in the larger cities Item 4 would assume even greater importance unless the city had its own metered water service.

Relevant Law

As a result of the demands as stated, acts were passed from time to time so that it is now legal to charge a sewer rent in first class townships, boroughs and third class cities.

The Act of 1931, known as the Township Code, changed the wording to make the collection of the rental at the will of the commission whereas the original acts made it mandatory to assess such a charge.

In the case of the borough, the Act of 1927 amending the Acts of 1915 and 1917, in addition to making the charge discretionary with the Aldermen, provides that a rental may be charged when the sewer is paid for wholly or in part at public expense, and further provides that the sum so collected shall not exceed the cost of operation, maintenance and interest on bonds or other costs legally chargeable to the expense of the sewer. The act also provides that the charges shall be collected by the officer authorized to collect borough taxes and that the charges are to be apportioned equitably among the users of the sewers. It also makes the charge a lien upon the properties, to be collected as other liens are collected, or by seizure and sale of personal property on the premises.

The act relative to third class cities, which is practically the same as that relative to the borough, was passed in 1925 and is an amendment to the Act of 1913.

Basis of Charges

There are several ways to determine the basis of charge. The first, which is the more equitable, is to bill for the amount of sewage contributed. Because of the small sizes of the services to the individual houses and the amount of solids contained in such sewage, it has not been practical to meter the connections, but with the exception of certain industrial establishments in which water enters into the creation of the products, the use of the meter on the water service has been found to be a good indication of the relative amount of sewage produced.

The second method, that of charging upon a schedule of prices for fixtures connected with the sewer line, is of value when the water service is not metered or is owned by a private corporation.

In the establishment of the rates to be charged, much study must be given to the various items which enter into the annual costs, and as the township is the unit in which the most extreme cases are found, I will outline the conditions encountered in our township.

In the construction of a system of sewers, the costs of the main or intercepting sewers cannot be charged against the properties through which they flow, since the entire theory of assessment for sewer construction is on the basis of eventual benefit to the property assessed, and, therefore, the amount which can be assessed must be based upon the cost of a sewer of sufficient size to serve only the property in question. The excess cost is an item which must be carried by the entire community and is usually provided for by the issuance of sewer bonds, generally of long term.

When there are different watersheds in the township it also becomes necessary to provide many treatment works or to establish pumping stations to lift the sewage over the divide so that it may be treated more economically at a central plant. The township code provides that sewer districts

may be established and the cost of the pumping stations and intercepting sewers may be assessed against the entire sewer district but the provisions of the municipal lien act make necessary the filing of liens for improvements within six months after completion of the work. This would mean that properties on the watershed which might not be connected to or have sewers in their vicinity for years would be assessed before receiving the benefit of sewers. For this reason the charges for pumping stations and treatment works are included in the amount charged to the bond issue.

Although the cost of branch service sewers constructed in public roads can be assessed directly against the abutting property, provision must be made for corner properties abutting on two or more sewers and for the length of the sewer which is included in the intersection of the street lines as well as for property which, by reason of topographical features, is unable to use the sewer. These charges are likewise included in the bond issue.

In addition to the sinking fund and interest on the bonds, other annual costs include the cost of operation and superintendence of the pumping stations or disposal plants; the costs of superintendence and operation of the sewer system, including a periodical flushing of the system if the pipes are small and the flows so small that deposits are inclined to lie in the sewer. Inasmuch as the smallest sized sewer which can be maintained in a satisfactory manner is too large from a hydraulic standpoint when only several connections are made in a block and the flow is limited to domestic sewage, such deposits are likely to occur in some of the laterals.

Another item which enters into the calculation in many communities is the charge for the use of sewers in adjoining municipalities and in some cases, when many political bodies use a joint disposal plant, the share of the cost of disposal also must be taken into consideration.

After the total annual cost has been found, there still remains the task of dividing the cost among the various users of the sewer.

As there are not many townships which have their own water supply, and since the solution by billing on a metered basis is a simple one, this paper will consider only the billing on a flat charge or on a sliding scale. Under this plan the amount of water used in the various plumbing fixtures is considered and a charge is made for each fixture connected with the sewer. The relative values are shown in the following annual charges taken from the ordinance adopted by Lower Merion Township:

Sinks—$3.50 for first; $1.50 for each additional
Water closets—$2.50 each
Basins—$1.00 each
Stall showers—$1.00 each
Bath tubs—$1.50 each
Laundry tubs—$1.00 each part.

The minimum rental for dwellings—$4.00 per year; other buildings—$5.00 per year. Factories, hospitals and colleges are given special rates at the judgment of the committee appointed to have charge of the sewers. In some cases the rate for this type has been placed at a flat rate of $1.00 per person per year for the number of persons using the building.

Practical Application

The application of the above schedule by Lower Merion Township has resulted in an income in excess of the amount needed to defray the costs of operation and maintenance and to pay the sinking fund and interest on the bonds, so that, from time to time, reductions have been made in the charges to private dwellings by fixing a certain percentage to be deducted from the bill for this class of service. At this time the amount of discount is thirty per cent, with a further discount on all bills of 5 per cent if paid within the first three months of the year. As the connections are increasing, while the original bond issue is about to be cancelled, it would seem that further reduction can shortly be made.

The provision of the discount for prompt payment has proved to be a wise one since it supplies an incentive to pay the bill and provides money at a time when the township is forced to operate on borrowed money inasmuch as taxes cannot be collected under existing law before the middle of September.

Bills are issued annually on January second, and since the charge is so low, $7.35 for a house with one bathroom and $10.85 for two bathrooms, the issuance of bills at closer intervals has been considered as a needless expense.

During 1930 the cost of operation and maintenance amounted to $107,833.68 while 7178 bills produced a revenue of $107,141.61

The work of keeping the records has proved to be a small item. When an application is made to connect with the sewer system, a number is given the connection, three cards are issued and the name of owner and location of the property is entered in the sewer connection record book.

One of the cards, the lateral record card, is issued in duplicate and contains beside the permit number a record of the location and conditions encountered in laying the connection. This card is filled out by the person who makes the lateral inspection and is used both as a record of the location and in preparing the estimate for the lateral contractor.

The second card, the house connection card, is filled out by the plumbing inspector and contains beside the permit number and location a sketch of the location of the trap and point of entry into the house and the date of inspection.

The third card, the record of plumbing fixtures, is placed in a file from

which the cards are removed monthly. Inspections of the houses listed on the cards reveal those which have been occupied during the preceding month. If a property is found which has just been occupied, the name of the owner is secured and a count is made of the fixtures in the house.

At the time of filing the application, an entry is made in the sewer record book and when the "Record of Plumbing Fixtures" card is returned to the office the information is entered on the sewer record sheet, the bill for a fractional year is issued and given a number from the sewer rent docket which is made up with a serial number for each bill.

As against this record the plumbing inspector turns over his report of all houses which have received the second or final plumbing inspection and lists thereon the number of fixtures at the time of his report. The two counts have been found to be necessary since many changes are made between the time a house is first completed and the original occupation of the property, together with the fact that errors in billing, which are a source of annoyance to the property owners and require an additional visit to the house in order to satisfy both the owner and the township, are thus reduced to a minimum.

Writing of sewer rent bills, which requires the service of one clerk for three months, is started around the first of October. The bills which have been entered in the sewer rent books are numbered serially for the year and then forwarded to the last known address and owner.

Upon completion of the billing, docket sheets both for current and delinquent bills are typed in duplicate, giving the permit number, bill number, location of property and face amount of the bill.

Reminder stickers are placed on all bills for properties which have unpaid bills for former years which have not been liened, and on January second stickers are removed from such delinquent bills as have been paid to that time and the bills are placed in the mail.

Under existing law no plumbing work may be done in a house without first obtaining a permit from the local Board of Health and from this record the number of fixtures installed or taken out is entered on the sewer rent books.

As many owners are not familiar with the law, fixtures are often installed without first obtaining the permit and it is therefore necessary to make periodical inspections of the fixtures in all buildings. Such counts are made at intervals of about eight years and have resulted in an addition of from $3000 to $4000 for each inspection with the cost of inspection about $1000.

Costs of Collection

The actual collection of the rental after the bills have been mailed may be done either by the department in charge of the work and then

turned over to the township treasurer, or may be collected by the treasurer on a duplicate of the bill list.

In Lower Merion Township the treasurer collects the money from the property owners and receives as his compensation one-half of one per cent of the total collected, but unless this rate is established thirty days before the election of the treasurer he is entitled to retain one per cent of all such money which he collects. In several townships surrounding Philadelphia, the money is collected by the force which takes care of the books and issues the bills and is then turned over to the treasurer.

Liens are filed at the end of three years for all bills which have not been paid and although this is an expensive process, the annual number of bills so liened, twenty-seven in 1930, is so small that this method of collection is shown to be efficient and acceptable to the general public.

The Act of 1919 provided that liens must be filed for sewer rentals within three years after the bill became delinquent and liens were accordingly filed for bills back to 1916. At the close of the records for the year 1930 there were on the books only twenty bills for the years 1916 to 1924, inclusive, fourteen were still owing for 1925, thirteen for 1926 and thirty-five for 1927. For the three years which were not liened 107 were chargeable to 1928 or 1.6 per cent of the total number issued for that year, 419 were chargeable to 1929 which was 6.1 per cent of the total and 992 or 13.7 per cent of the total issued for 1930 remained unpaid.

The total value of all bills unpaid for the years from 1916 to 1927 amounts to but $746.05 which is the total of the amount liened for these years. Outstanding bills for 1930 were $11,335.23, for 1929 were $4384.07 and for 1928 amounted to $1104.36 (to which must be added $1386.95 due for years from 1908 to 1915 for which no liens were filed,) making a total of $18,956.66 for all outstanding bills of the past 22 years.

The following summary of the expenses of the Health and Drainage Committee (the sewer committee of the township) illustrates the various channels into which the rental is distributed:

Sinking Fund and Interest on Bonds	$ 36,930.50
Salaries (16 employees)	33,735.00
Power & Light (5 pumping stations)	15,827.42
Repairs—Stations (5 pumping stations)	1,877.16
Coal, Water, Oil (5 pumping stations)	597.32
Flushing, Sewer Cleaning—109 Miles on Main Sewer	12,910.42
Operation and Maintenance of 3 Automobiles	1,139.18
Office Expense and Telephones	1,584.21
Insurance	394.64
Sewer Rentals to Philadelphia & Haverford Township	2,068.98
Refund Sewer Rents—Duplicate Payments and Errors in Billing	768.85
	$107,833.68

Conclusions

In concluding, I would again point out the following:

1. Sewer rental is legal in Pennsylvania.

2. Sewer rental places the burden of the sewer costs on those who are benefited by their use.

3. It is the only positive way to guarantee the existence of an account sufficient to cover the expense of the work.

4. The work of securing the information to prepare the bills and of issuing the bills can usually be done by the persons employed to operate and maintain the sewers.

5. The time of issuance of bills gives the property owner an opportunity to pay part of his taxes at a different time of year.

6. It is not new. Lower Merion Township has used it since 1905, and Haverford, Radnor, Abington and Cheltenham Townships and the Borough of Jenkintown have used it since the completion of their original sewers.

Working Out Sewage Disposal Problems for the Marion County (Indiana) Tuberculosis Hospital, "Sunnyside"*

BY CHAS. BROSSMAN

Consulting Engineer, Indianapolis, Ind.

The Board of County Commissioners of Marion County, Indiana, were recently confronted with some unusual and knotty problems on the proper disposal of the sewage for the Marion County Tuberculosis Hospital. "Sunnyside" was started in 1916 and opened in 1917 with 72 patients and 20 employees. This population increased until 1927 in there were 250 patients and 90 employees. This number has continued up to the present time.

The original sewage plant consisted of septic tank and sand filters, on which some remodeling was done in 1924. This plant continued in operation until 1927, at which time bids were received and a contract let for a plant that should be good to serve a population of not over 500 persons. This plant was built and operated for two years with unsatisfactory results. The results of analysis of samples taken August 26, 1929, by the State Board of Health showed that the plant was not giving an effluent sufficiently purified to discharge into the creek. A further examination on October 10, by the State Board of Health, indicated that the plant was still not operating as it should and that the creek was in bad condition below the plant.

In April, 1929, the tanks were badly clogged up and filters were not operating at all, whereupon the entire septic tank system had to be cleaned. The filters were so badly clogged that the sewage would flow out the overflow tiles near the top of the filter.

It was found that the first few units of each battery of the septic tank were entirely filled with sludge, the sewage simply working its way through the first units, the sludge becoming less in the units further down the line, but all of them gradually filling up.

The sewage after leaving these three batteries of septic tanks, was conveyed to three rows of leaching tiles. We believe the object of these leaching tiles was to let the sewage filter out through the soil, the balance to go to the filter bed.

It was quite evident that this plant did not function properly. Neither could it be expected to do so, as the septic tanks were improperly proportioned. They were too small and they could not be cleaned out except by getting down into them and cleaning out the entire system.

* *Presented before the Fourth Annual Meeting of the Central Sewage Works Association, Madison, Wis., May 22, 1931.*

The Problem at Sunnyside.—The problem at Sunnyside was a little different than might obtain in some other plants, since this was a tuberculosis hospital. It was necessary that the sewage purification system provide adequate treatment through every step with final disposal so that no tubercular baccilli might endanger any one. This meant that everything had to be under cover, at least for the first two steps, that no sludge should be exposed.

With this in mind, it was decided to design Imhoff tanks and sprinkling filters, followed by sand filtration. Had the sewage not been tubercular, we might have considered omitting the sand filters and substituting chlorination. However, we considered that chlorination would not be effective on tubercular sewage, consequently final sand filter treatment was necessary, due to the conditions in the stream below the treatment works.

Old Tank.—The original disposal plant consisted of an ordinary septic tank, of which the tank proper was approximately 28 ft. long, 10 ft. wide and 7 ft. deep below the water line. This tank has a siphon chamber at the end which discharged the partially clarified sewage into a filter bed 55 ft. by 72 ft. and from this the sewage was discharged into Indian Creek. Indian Creek is a small stream east of the institution, which discharges into Fall Creek. Located on Indian Creek about one mile away, is a girls' camp of the Salvation Army. The creek is used for bathing purposes, and the farmers below the institution also use the water for their stock.

A few years ago an artificial lake was created, known as Indian Lake, where a suburban residential district was platted. Below the point of discharge, in Fall Creek, was a Boy Scouts' camp, and this creek was also used for bathing. Indian Lake, as a pleasure resort, was used for bathing and pleasure purposes.

To keep the cost at a minimum, it was decided to utilize and remodel the old septic tank. This tank was too small in its present state to be used as a septic tank. Furthermore, it was not desirable to use this type of tank, as it would not give the best results. Neither was it deemed advisable to abandon it entirely, due to the money already spent. This same condition held in regard to the filter bed, which was too small to be used as a filter bed in itself, but which when used in the manner prescribed, as the third step in treatment was of ample size.

Before designing the plant, tests were made over a considerable period, to determine the character of the sewage, the solids contained therein, and the rate of flow. The plant was then designed on the basis of a future population of 600 at 100 gallons per capita, or a total flow of 60,000 gallons per day. The original preliminary estimate of the cost of such a plant was stated at $28,000.

Old Tank Remodeled.—The old septic tank was remodeled as an

Imhoff tank. This tank was built of reinforced concrete and the superstructure was made of similar material, using glass sides and a glass roof over the greater portion.

The sludge-drying bed was in the same building, directly opposite the Imhoff tank, and so arranged that scum could be applied and dried. (Fig. 1.)

The rotary filter building is also built of reinforced concrete throughout including the superstructure. The roof was made of 2-inch tongue-and-groove wood plank with a composition roof. The roof is dome-shaped, with a large copper ventilator in the center.

FIG. 1.—"Sunnyside" Treatment Works. Imhoff Tank, Sludge Drying Bed and Incinerator.

The filter is 40 ft. in diameter and 6 ft. deep. (Fig. 2.) The rotary distributor is of the Pacific Flush-Tank Company design, with umbrella-type housing, and completely enclosed ball bearing at the top, from which the distributor is hung. The ball bearing is adjustable in several different ways for lining up. It runs in a bath of oil, having a large oil reservoir so that a single oiling is sufficient for a long period. The entire rotary distributor is built of aluminum, making it very light, and a special composition is used to resist corrosion.

Sand Filter.—The sewage after leaving the rotary filter is discharged through a siphon onto the sand bed, which is approximately 3 feet deep.

In this instance the old concrete structure was used, after removing the old stone and cinders, then laying a new underdrainage system, placing the sand and distributors in the customary manner. This bed is left open as the sewage, before reaching this bed, has passed through the Imhoff tank, trickling filter and humus tank.

The humus tank is located between the sprinkling filters and the sand filter, and has a detention period of forty-five minutes to one hour.

The buildings present a very pleasing appearance architecturally. (Fig. 3.) Great care was taken to make them of suitable appearance,

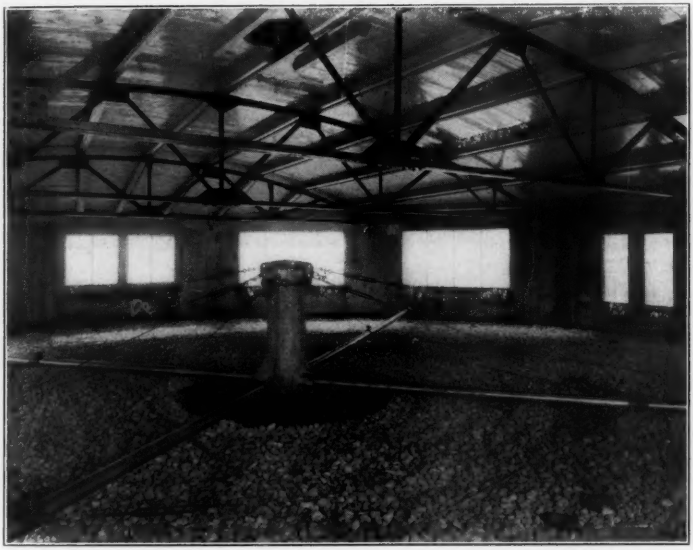

FIG. 2.—"Sunnyside" Treatment Works. Trickling Filter with Pacific F.-T. Rotary All Aluminum Distributor.

with proper landscaping to be added later, so that the entire effect would be harmonious. To one walking near this plant, there would be no intimation that it had anything to do with sewage, as there in nothing to signify what is inside.

A small laboratory has been provided so that the operator can make a few simple analytical tests. Tools have also been provided for skimming the scum from the top of the tank and placing it promptly on the drying beds. All sludge that is collected in the tanks is pumped into the sludge beds by simply throwing a switch, and after the sludge is dried, it can be burned in the enclosed incinerator.

The entire plant was built for considerably under the estimate, the contractor's price being approximately $20,960. Approximately $400 worth of small additions found desirable, due to conditions found after getting into some of the old work, made the total cost of the plant about $21,300, exclusive of engineering.

Operation of Plant.—When the plant was started up the digestion compartments of the Imhoff tank were of course not seeded, and more or less difficulty was encountered in producing satisfactory sludge. Attempts were made to seed the tank from the old septic tank sludge, but after putting this in, it was found that the old sludge was acid, with a low pH value.

FIG. 3.—"Sunnyside" Treatment Works. Covered Structure for Imhoff Tank, Sludge Beds and Incinerator to the Right, Trickling Filter to the Left.

After the plant had run awhile we found that one of the sand beds was clogging. Tracing this back, we found that the stone sprinkling filter was not yet operating properly. Considerable colloidal material was carried over, and it was known that the Imhoff tank was not operating as it should. Very finely divided matter was held in suspension, and Mr. Bennett, the operator and chief engineer of the plant, seemed to think this was due to the wood fibre toilet paper being used.

Burlap sacks were placed in the flowing-through chambers and humus tank as a temporary expedient to act as a screen to remove the finely divided precipitate from the effluent. This cleared up the effluent considerably, but only for a few days, because the burlap soon became covered with a gelatinous mass and had to be removed as it became rotten and fell

into the tank. By this time lime had been added to the tank and it was not necessary to continue using the burlap screen. The burlap removed enough of the suspended matter from the effluent to prevent the clogging of the sand beds.

On April 20, 1931, sludge in the gas vents arose to within a few inches of the top, caused by the acid condition of the sludge. This sludge was removed and placed upon the sludge-drying bed and after drying for three weeks, was shoveled off and burned.

When lime was placed in the Imhoff tank, it was introduced into the sludge lime, the pump was started and the sludge was recirculated back into the tank.

We worked with the State Board of Health in an endeavor to correct the pH conditions at this plant. When raw sewage enters the plant it has an average pH of 7.8. After the plant had been in operation a few weeks, it was found that the effluent from the Imhoff tank contained finely divided particles of suspended matter which deposited on the surface of the sand beds, which became clogged within ten days to two weeks. On examination it was found that they were covered with a very thin coating of brown substance resembling the suspended matter in the applied liquor. One theory as to the cause of this, was that no film had formed on the stone of the trickling filter, due to cold, unfavorable weather; and another was that the pH of the Imhoff sludge was too acid.

The sludge in the Imhoff tank showed a pH of 6.8, which was considered to be too acid. To correct this acidity 100 pounds of lime was added. This amount of lime raised the pH to 8.4, but within twenty-four hours it had fallen to 7.6 and within another twenty-four hours to 6.9. Forty pounds of lime was then added. Since then it has been necessary to add lime every two or three days. Four hundred pounds of lime have been added so far, and the pH will not hold the correct level without the addition of lime.

The correction of the pH has removed the suspended matter from the effluent and no more clogging of the sand beds has occurred.

The operator checks the pH every day and it is not difficult to tell when the reaction is wrong for when it is, a very offensive odor comes from the Imhoff tank and a heavy coating of sludge containing undigested raw sewage solids forms on the gas vents and on several occasions foaming has occurred.

A similar plant located at a tubercular hospital in Kentucky has the same trouble in maintaining the proper reaction, but it was finally corrected with lime.

Care of Plant.—Every morning the operator thoroughly stirs the scum that accumulates on the gas vents in order to cause it to settle. He then washes down the sides of the gas vents thoroughly with water; skims the

entrance chambers, and deposits this matter in a container. It is later buried because of its offensive and dangerous nature. The operator checks the pH value and adds lime if necessary. Once a week the arms of the rotary distributor filters are cleaned with a wire brush and flushed out with water.

It has been found best to use only one side of the Imhoff tank at a time, changing over once a week. The same policy is followed in the operation of the sand beds. This gives the idle sand bed time to dry, after which any coating on the surface can be raked off.

It took the rotary filter six to seven weeks to become seeded. At this time there are great numbers of *psychoda*, or filter flies, present.

IMHOFF TEST FOR SUSPENDED MATTER

Results in Cc. per Liter

	Apr. 9	Apr. 14	Apr. 17	Apr. 24	May 8	May 19
Raw Sewage	10	2	8	5	6	4
Dosing Tank	Trace	0.1	0.1	2	0.1	0.1
Inlet Humus Tank	0.5	0.1	Trace	1.3	Trace	Trace
Outlet Humus Tank	Trace	Trace	Trace	Trace	Trace	Trace
Plant Effluent	0	0	0	0	0	0

RELATIVE STABILITY OF EFFLUENTS

Percentage

	Apr. 9	Apr. 14	Apr. 17	Apr. 24	May 8	May 19
Inlet Humus Tank	27	13	21	13	21	21
Outlet Humus Tank	27	13	27	13	27	27
Plant Effluent	96	98	98	99+	..	..

Sand Beds.—The sand beds are the making of this plant. The effluent after leaving them is clear and sparkling and has a limpid appearance. The relative stability varies from 97 to 99 per cent. Some samples show better than 99 per cent.

Industrial Wastes and Stream Pollution

Relation between Biochemical Oxygen Demand and Volatile Solids of the Sludge Deposits in the Connecticut River*

By Willem Rudolfs

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In the course of an extensive and intensive investigation of the chemical and bacteriological conditions of the Connecticut River made during the years 1928 and 1929, in connection with the water diversion case between the States of Connecticut and Massachusetts, a mass of data was collected which is of considerable theoretical and practical interest. The Attorney-General of the State of Connecticut has granted permission to publish the material.

Surveys of the Connecticut River bottom showed that a number of sludge banks existed, which varied considerably in extent and thickness. Analyses of the materials indicated that the materials deposited at different places were apparently somewhat different in composition.

Location of Sludge Beds

Before making detailed surveys of the deposits, a preliminary trip by boat was made over those reaches of the river where sludge deposits appeared likely to occur and to determine the approximate magnitude and location of the beds. In general, deposits of appreciable size could be located by observing bubbles on the surface of the river, indicating that septic action was taking place. In areas where sludge beds were expected to form, a weight was drawn along the bed of the river to uncover bubble evidence of septic action. In this manner the location of relatively inactive sludge deposits could be determined. With the aid of a stadia transit a survey was made of the extent of the deposits. In general, the areas of the sludge deposits were fairly well defined and easily measured.

Measurements of the depth of the sludge deposits were made from the surface of the deposits to hard bottom by probing with a sampling rod. The depths of the deposits varied, the sludge concentrating in depressions in the bed of the river.

* *Journal Series Paper, presented before the 82nd Meeting of the American Chemical Society, Buffalo, N. Y., Sept. 2, 1931.*

Sampling

A series of samples was taken in May and June, 1929, after spring freshets had scoured the river and sludge deposited near sewer outfalls had been carried downstream. A second survey was made and a second series of samples was taken in September and October, 1929, in order to determine, if possible, the accumulation of sludge during low flow in the summer. Rainfall during the summer of 1929 was below normal and a rather low river stage resulted in practically no scouring velocities. Samples were collected in two different ways. These two types of samples were designated as "core" and "skim." Core samples were collected with an apparatus designed for the purpose, with which it was possible to obtain a cross-section of the depth of the bed. Skim samples were collected by drawing a flat-sided container along the bed of the river in such a manner as to skim a sample of sludge from the surface of the deposit. It was felt that the results obtained on skim samples could be correlated with the area of the deposits to give one of the characteristics of the deposits, while the results obtained from analyses of cores samples could be correlated with the volume of the deposit, thus giving another characteristic. In practice it was found that the samples collected did not vary greatly and in presenting the results all the analytical data have been averaged. At least four composited samples were collected from each deposit of appreciable size.

Results

In total 32 sludge beds were located, surveyed and analyzed but results are presented only from those sludge beds which were surveyed and analyzed both in June and September.

The area of the sludge beds varied from 22,000 to 484,000 square feet and the volume from 41,000 to 1,147,500 cubic feet.

The average B. O. D. results, volatile solids (dry basis), and organic nitrogen, expressed in kilograms, are presented in Table I. The 20-day B. O. D. was calculated from 5-day B. O. D. determinations, assuming the latter to be 68% of the 20-day demand. The main source of sludge banks Nos. 1 to 3 was Springfield, Massachusetts, and surrounding territory, No. 2 being located at about the Massachusetts-Connecticut state line and No. 3 a short distance below. Sludge banks farther downstream were surveyed and analyzed only once. The second group of sludge banks was located near Hartford, Connecticut, and surrounding territory. They extended over a distance of about 13 miles as isolated deposits. In general, the deposits nearest the sources of pollution showed a considerable increase in volume, amounts of volatile solids, B. O. D. and organic nitrogen in the fall as compared with the spring, whereas the sludge banks farther downstream showed in general a decrease.

TABLE I

AVERAGE B. O. D. DRY VOLATILE SOLIDS AND ORGANIC NITROGEN OF SLUDGE BEDS IN JUNE AND SEPTEMBER

Sludge Bank No.	Miles from Source	June B. O. D. (20 day) Kg.	June Dry Vol. Solids Kg.	June Organic-N, Kg.	September B. O. D. (20 day) Kg.	September Dry Vol. Solids Kg.	September Organic-N, Kg.
1	0–1	25000	162000	5020	29400	238000	7120
2	4	76300	780000	23380	49400	453000	14520
3	6	16550	19400	6640	19100	173000	6060
9	0	76800	530000	11100	104000	647000	15100
10	1	97500	762000	20730	120300	888000	25400
11	2.6	56200	582000	18030	43800	390500	13800
12	2.7	25000	257500	7640	22500	256000	7750
13	4	23650	275000	9570	?	?	?
14	4.6	60600	833000	23800	102500	1235000	35600
15	6	40300	600000	18100	62000	728000	20700
16	9.4	31600	524000	13400	19800	302000	8660
17*	9.6	55400	663000	20850	40700	568000	17750
18	13.1	3020	50500	1520	710	11750	335
19*	13.7	11000	137200	3110	12250	124200	2520

* Additional source.

If a calculation is made of the kilograms B. O. D. per kilogram volatile solids present in the different sludge beds (Table II) during June and September, a rapid decrease is shown in B. O. D. of the beds farther removed from the source of pollution. Plotting these results for sludge beds Nos. 9 to 18 against the distance in miles removed from the main

TABLE II

RATIOS OF B. O. D. AND ORGANIC NITROGEN IN RELATION TO DISTANCE FROM POLLUTION CENTER

Sludge Bank No.	Miles from Source	June Kg. B. O. D. per Kg. Vol. Solids	June Kg. B. O. D. per Kg. Org. N	June % Org. N	September Kg. B. O. D. per Kg. Vol. Solids	September Kg. B. O. D. per Kg. Org. N	September % Org. N
1	0–1	0.1550	4.96	3.12	0.1227	4.12	3.00
2	4	0.0975	3.26	2.99	0.0910	3.37	2.70
3	6	0.0952	2.80	3.41	0.1220	3.15	3.86
9	0	0.1445	6.95	2.07	0.1605	6.90	2.33
10	1	0.1286	4.68	2.73	0.1352	4.73	2.86
11	2.6	0.0965	3.10	3.10	0.1120	3.15	3.53
12	2.7	0.0968	3.21	2.97	0.0878	2.89	3.03
13	4	0.0857	2.47	3.47	....	..	..
14	4.6	0.0727	2.54	2.86	0.0870	2.86	2.88
15	6	0.0672	2.26	2.97	0.0848	2.98	2.90
16	9.4	0.0603	2.36	2.56	0.0657	2.24	3.12
17*	9.6	0.0818	2.58	3.16	0.0716	2.29	2.86
18	13.1	0.0598	1.99	3.01	0.0605	2.12	2.85
19*	13.7	0.0802	3.52	2.27	0.0990	4.87	4.92

* Additional source.

source (Fig. 1), a set of curves is obtained which shows the degree of reduction of the B. O. D. of the volatile solids. Whereas the volatile solids near the source of pollution required 144.5 kilograms oxygen per kilogram, 9.5 miles downstream the requirements were only 60.3 kg. oxygen per kg. volatile solids. Farther downstream, below entrance of additional pollution, the same phenomenon is repeated.

The percentage of organic nitrogen present in the sludge beds (Table II) varied somewhat for the different deposits. On the basis of the percentage it would appear that no great variation took place, although in general the percentage of organic nitrogen was perhaps somewhat greater in the fall than in the spring. This would indicate that organic nitrogenous com-

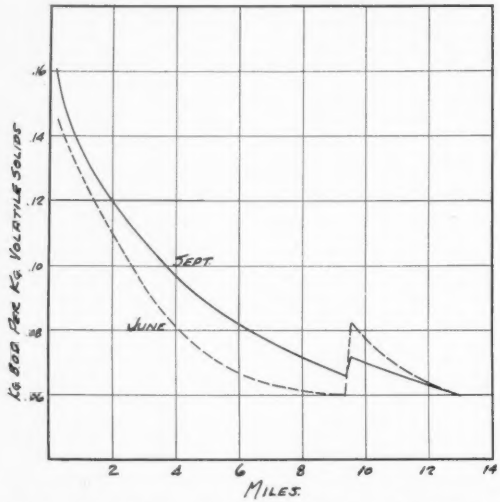

FIG. 1.—Ratio of B. O. D. and Volatile Solids in Sludge Deposited Downstream from Source, Connecticut River.

pounds, remaining approximately constant in percentages in the sludge deposits downstream, were stabilized at about the same rate as the carbonaceous substances. An attempt was made to show the tendency of the changes in B. O. D. as correlated with organic nitrogen by calculating the ratios between the oxygen demand and the organic nitrogen. If the rate of decrease in B. O. D. were less for the organic nitrogen than for the volatile solids it could be assumed that the rate of stabilization of the former was less than that of the latter. If, on the other hand, the rate of decrease were greater, it could be assumed that certain nitrogenous compound changed more rapidly than the organic matter of the complex mass

TABLE III

PERCENTAGE DECREASE IN B. O. D. FROM SOURCE TO DIFFERENT STATIONS

Sludge Bank No.	Miles	June		September	
		Vol. Matter	Org. N	Vol. Matter	Org. N
9	0	..	..	..	..
10	1	11.2	32.5	15.7	31.5
11	2.6	33.2	55.3	30.3	54.5
12	2.7	33.2	53.8	45.3	58.1
13	4	40.7	64.5	..	..
14	4.6	49.7	63.4	45.8	58.5
15	6	53.5	67.5	47.2	56.8
16	9.4	58.2	66.0	59.1	67.5
17*	9.6	43.3	62.9	55.4	66.8
18	13.1	58.6	71.3	62.3	69.3

* Additional source.

as a whole. These calculations, part of which are plotted in Figure 2, indicate that the ratio between B. O. D. and organic nitrogen changes somewhat more rapidly than the ratio between B. O. D. and the total

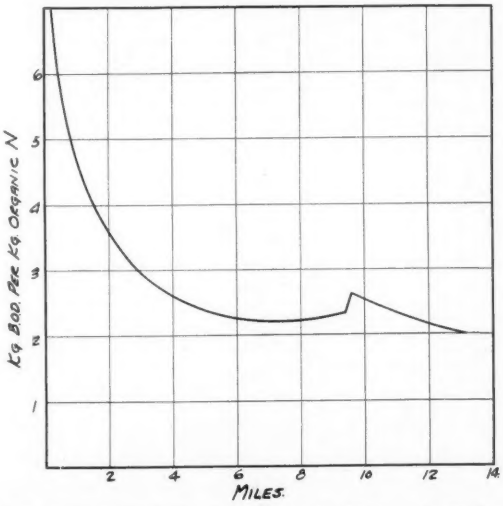

FIG. 2.—Total B. O. D. per Kg. Organic Nitrogen in Sludge Beds, Connecticut River.

volatile solids. This is perhaps shown even more clearly in Table III where the percentage decrease in B. O. D. for both total volatile solids and organic nitrogen are given for sludge deposits near the source and sludge beds downstream.

The more rapid decrease in B. O. D. for the first few miles would tend to indicate that the remaining mass or residue is more difficult to stabilize the older it gets. To be sure, the total quantity of oxygen required decreases but the residue is more resistant and requires considerably more time to be stabilized. When the percentage B. O. D. remaining to be satisfied is plotted (Fig. 3) this tendency is very well shown.

The apparently more rapid rate of decrease in the B. O. D. of organic nitrogen might be explained in somewhat the same way. Easily stabilized substances are rapidly oxidized, whereas a part of the organic nitrogen (living complexes?) is more resistant. Van Suchtelen[1] recently has advanced

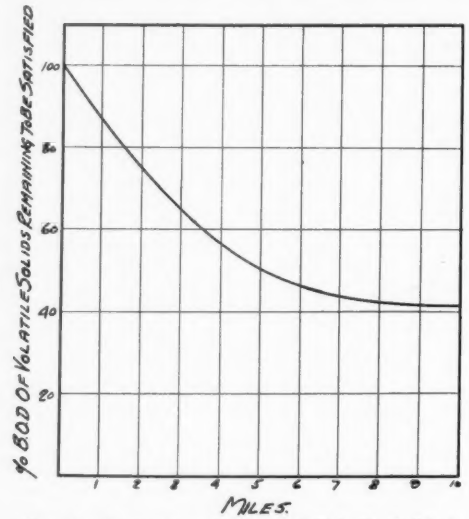

FIG. 3.—Percentages B. O. D. of Volatile Solids in Sludge Deposits Remaining to Be Satisfied, Connecticut River.

the theory that the greater the molecules the greater the difficultly of oxidation of the organic compounds. The increased difficulty may be due either to the remaining compounds or to a rearrangement of oxygen in the molecule. Without attempting to present this theory as an explanation of the observed resulted, namely, that the percentage B. O. D. of volatile solids remaining to be satisfied decreases slowly when sludge deposits are farther removed from the source, and might either be considered to be older or to have had the benefit of coming in contact with greater quantities of dissolved oxygen in the water, it is of interest that this explanation could be applied. It is also a fact that organic solids, anaerobically decomposed,

decrease from the peak of B. O. D. at first very rapidly and thereafter at an increasing slower rate.

The growth of the sludge deposits near the sources of pollution, which took place during the summer months, as contrasted with the decreased volume of the deposits farther removed from the source, was in all probability due to the fact that during the summer of 1929 the velocity of the river was low. A dry period of considerable length caused a run-off far below the average for the previous 20 years.

Summary

Surveys of the Connecticut River bottom made after the spring freshets and again in the fall showed a number of sludge banks to be present, which varied considerably in extent and thickness. Comparing the results obtained early in summer with those obtained in the fall, the deposits nearest to the sources showed increase in volume, amounts of volatile solids, B. O. D. and organic nitrogen in the fall, whereas the sludge banks farther downstream showed in general a decrease. The percentage organic nitrogen in the sludge beds did not vary greatly. The B. O. D. values decreased rapidly during the first few miles and more slowly thereafter, indicating that the remaining residue was more resistant. It appeared that the nitrogenous compounds were stabilized at about the same rate as the carbonaceous substances. The growth of the sludge beds nearest the sources was in all probability due to decrease in velocity of flow during the summer.

Reference

[1] Van Suchtelen, SEWAGE WORKS JOURNAL, **3**, 588 (Oct., 1931).

Biological Purification of Creamery Wastes *

BY MAX LEVINE

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Purification of creamery wastes has become a vexing question in many localities. In some instances city officials have prohibited creameries from discharging wastes into municipal sewerage systems because of fear of disrupting the city sewage disposal plant. Is there any basis for this apprehension and, if there is, what are the properties or peculiarities of creamery wastes that render them so troublesome? These questions may best be answered by comparing municipal sewage and creamery wastes as to composition, and by consideration of the nature of the changes taking place when these wastes are subjected to sewage treatment processes.

The oxygen consuming power and the concentration of nitrogenous substances are two convenient measures of the character of sewage or trade waste. Ordinary sewage rarely contains over 25 milligrams of nitrogen (as NH_3 and organic nitrogen) per liter, whereas creamery wastes generally contain about twice as much, and not infrequently four to six times as much nitrogenous matter. The really significant difference, however, is with respect to the oxygen-consuming properties. Muncipal sewage generally consumes about 50 milligrams of oxygen per liter when treated with an oxidizing agent such as potassium permanganate, whereas creamery wastes similarly treated consume from 600 to 1500 milligrams of oxygen, or 12 to 30 times as much as domestic sewage.

The ratio of oxygen-consuming to nitrogenous constituents in domestic sewage is about 2.5 to 1, whereas in creamery wastes it is generally 10 or 12 to 1. This high ratio is due to the presence, in creamery wastes, of lactose (milk sugar) which is practically, if not entirely, absent from domestic sewage. It is the presence of this lactose which is really at the bottom of the difficulties encountered in treatment. Why should one expect a municipal treatment plant, designed for domestic sewage, to treat adequately a trade waste so markedly different as regards quantity and quality of organic constituents?

When ordinary sewage enters a septic or Imhoff or other tank from which air is excluded, a large portion of the solids settles out; the clarified effluent, which has been but slightly changed as respects reaction, passes on to the filters or other purification devices, and the settled solids are gradually proteolyzed or digested, *i. e.*, transformed into liquid or gaseous

* *Presented before Meeting of the National Dairy Show, Cleveland, Ohio, November, 1930.*

materials. These latter changes are due to bacteria, which requires a neutral or slightly alkaline reaction for their activities.

A milk waste passing through a similar tank shows an entirely different train of changes. The milk sugar quickly becomes acid, causing precipitation of casein, the acid effluent is more difficult to treat, and the precipitated casein is not digested because of the acidity, which is germicidal to many of the digesting bacteria.

The determination which has been found to be particularly helpful in measuring effects of reaction on the activities of bacteria is the H^+ ion concentration. For convenience the so-called "pH" scale is employed to designate the H^+ ion concentration. This scale runs from pH 0 to pH 14. pH 7 is the neutral point. As the numbers decrease the acidity increases and vice versa, increasing numbers on this scale indicate decreasing acidities or increasing alkalinities. Thus, pH "0" is the most acid and pH "14" the most alkaline.

Several points on this scale should be particularly noted with respect to the biological disposal of creamery wastes

1st, the neutral point is at pH 7.0.

2nd, decomposition or digestion of casein and other organic nitrogen compounds takes place best at a slightly alkaline reaction, pH 7.4–7.6.

3rd, this protein digestion is distinctly and markedly inhibited at moderately acid reactions, pH 5.5.

4th, at slightly more acid reactions, pH 5.0, many of the casein-digesting bacteria are killed, and

5th, if the acidity reaches pH 4.2–4.4, the casein is precipitated, and the rate of protein decomposition, in the absence of air, falls to a minimum.

The rate of decomposition of casein and other proteins may be conveniently measured by determining the amount of ammonia and amino nitrogen produced in a given time. The influence of the reaction on such decomposition is illustrated in Table I, from which it is evident that digestion takes place best at pH 7.0 to 7.4, is markedly arrested at pH 5.0

TABLE I

EFFECT OF INITIAL REACTION (H^+-ION CONCENTRATION) ON DIGESTION OF GELATIN

Initial Reaction, pH	Organism: *Flavobacterium suaveolens* — Increase in Ammonia and Amino N, in P. p. m. (6 Days 20° C.)	Organism: *Bacterium cloacae* — Increase in Ammonia and Amino N, in P. p. m. (6 Days 20° C.)
4.6	0	0
5.0	53	0
5.5	627	158
6.4	665	211
7.0	770	211
7.5	704	211
8.4	680	129

to 5.5 and practically completely stopped at greater acidities. Thus, one type of bacteria (*Flavobacterium suaveolens*) liberated 770 mg. of ammonia and amino nitrogen per liter from gelatin when the reaction was neutral, pH 7.0, but only 53 mg. when acid, pH 5.0.

The next question which naturally arises is—what reaction will develop if creamery wastes are stored in septic or other tanks, as has frequently been advised in the past? To ascertain this point, five creameries in Iowa were visited on each of several days, and samples were collected at the sewer outlet every 30 minutes for the entire day's operating period. The analyses of such 24-hour composites are shown in Table II, where the effect of storage in the absence of air is also indicated. It is evident that inhibiting acidities developed in 12 of 16 samples collected and that in 8 of these cases the acidity was sufficiently high to kill many of the protein-digesting bacteria.

TABLE II

COMPOSITION OF CREAMERY WASTES* AND EFFECT OF ANAEROBIC STORAGE ON REACTION

Creamery	Date	Oxy. Cons.	Nitrogen Org.	Nitrogen NH_3	As $CaCO_3$, Acidity, Stored 2d Initial	As $CaCO_3$, Acidity, Stored 2d Day	pH Stored 2d Day	Approximate Equivalent Skim Milk
		Analysis in P. p. m. (Milligrams per Liter)						
B	8/22	365	41.6	0.4	30	160	5.8	1.0%
	8/25	1250	117.5	2.5	70	570	4.2	3.0%
D	8/21	670	33.0	12.0	Alk.	320	5.9	1.5%
	8/27	550	56.5	3.4	Alk.	120	6.4	1.0%
N	8/4	3360	286.0	14.0	350	900	3.9	7.0%
	8/8	1630	77.5	2.5	100	690	4.1	3.0%
R	8/7	400	24.6	3.4	Alk.	110	7.2	1.0%
	8/13	2960	282.0	18.0	240	880	4.3	6.0%
	8/14	995	84.0	6.0	100	330	5.8	2.0%
	9/9	1980	237.0	13.0	200	900	4.7	4.0%
	9/11	1560	131.0	9.0	90	750	4.3	3.0%
	9/16	1300	141.0	9.0	70	445	4.8	3.0%
S	7/31	590	58.6	3.4	25	80	6.2	1.0%
	8/15	285	23.8	1.2	50	65	6.5	0.5%
	9/3	885	93.0	2.0	60	430	4.8	2.0%
	9/10	660	55.0	5.0	110	320	5.0	1.2%
1% Skim Milk		400–450	40–45	1–2			5.3	1.0%

The problem of biological disposal of creamery wastes resolves itself into that of devising means for destroying milk sugar without development of detrimental acidities. If milk wastes and sewage are stored in the absence of air, there are developed from this sugar such compounds as the relatively strong lactic acid and extremely ill-smelling butyric acid,

* Composites for 30-minute samples on day examined (1924).

whereas if an abundance of air is supplied, these undesirable acids are oxidized to the unobjectionable carbon dioxide. Exposing the waste to oxygen by bubbling air through it, as is done in the activated-sludge process or by permitting the sewage to trickle over well-aerated beds of cinders or broken rock instead of keeping the air away, is the underlying principle of biological disposal of creamery waste.

Experiments along these lines have been in progress at the Engineering Experiment Station of the Iowa State College for a number of years and the results clearly demonstrate that aeration processes are dependable for the elimination of the lactose and prevention of the development of detrimental acidities.

The activated-sludge process was found to be effective in destroying milk sugar, but very large quantities of air were required; it was extremely difficult to maintain the sludge in suitable condition and the effluents were not stable. It is therefore felt that except under especially and peculiarly favorable conditions, the activated-sludge process is impracticable and not suitable for the average creamery.

Numerous and repeated observations with trickling filters prove conclusively that these devices are remarkably efficient for the removal of acid-producing materials. Some of the results obtained with a lath filter are shown in Table III. The filter consisted of six tiers of ordinary building lath, each tier being two feet square and one foot deep, with four-

TABLE III

EFFECT OF FILTRATION ON ELIMINATION OF LACTOSE FROM SKIM MILK POWDER SOLUTIONS

Depth of Filtration	Milk Concentration 1%	2%	4%	7%
	Reducing Substances Calculated as P. p. m. Lactose			
Raw Waste	321*	582*	1700	3254
1 ft.	Trace	86	294	1114
2 ft.	..	..	15	284
3 ft.	..	..	..	154
4 ft.	..	..	..	81
5 ft.	..	..	..	61
6 ft.	..	..	..	55
	Per Cent Reduction			
Raw Waste	00.0	00.0	00.0	00.0
1 ft.	99+	85.2	82.7	65.6
2 ft.	..	99+	91.2	91.3
3 ft.	..	..	99+	95.3
4 ft.	..	..	..	97.5
5 ft.	..	..	..	98.1
6 ft.	..	..	..	98.3

* Samples had stood for a long time before analysis (results lower than normal).

inch spaces between the tiers for sampling. Estimations of the efficiency of removal of acid-forming substances were made (1) by determining the quantities of milk sugar in the effluents from various depths of the filter, and (2) by ascertaining whether these effluents would develop appreciable acidities on anaerobic incubation.

The waste was applied to the filter at a rate of 800,000 gallons per acre per day for 10 to 14 hours daily. Under these conditions practically all of the sugar was removed from a four per cent milk solution by three feet of filtration.

The reactions of the effluents after storage for two days in the absence of air are shown in Table IV.

TABLE IV

REMOVAL OF ACID FORMING MATERIALS BY FILTRATION OF MILK SOLUTIONS

Depth of Filtration	Milk Concentration 0.5%	1%	2%	4%	7%
	pH of Effluents Stored 48 Hours (20° C.)				
Raw Waste	6.4	6.9	4.6	4.3	4.2
1 ft.	7.4	7.1	6.6	5.3	4.6
2 ft.	7.6	7.5	7.2	6.6	5.8
3 ft.	7.5	7.5	7.3	7.1	6.5
4 ft.	7.5	7.3	7.5	7.4	6.9
5 ft.	7.5	7.5	7.6	7.5	7.2
6 ft.	7.5	7.5	7.6	7.6	7.3
	Acidity of Effluents Stored 48 Hours. Expressed in P. p. m. $CaCO_3$				
Raw Waste	120	255	400	620	870
1 ft.	20	45	130	250	640
2 ft.	20	30	50	100	290
3 ft.	20	20	20	50	175
4 ft.	20	20	15	30	110
5 ft.	20	20	10	20	80
6 ft.	20	20	10	20	60

Each of the concentrations of milk employed became distinctly acid on anaerobic incubation, the higher concentrations developing germicidal acidities. Such wastes could not be admitted indiscriminately to city septic or Imhoff tanks. After biological filtration the effluents remained alkaline, the depth of filtration for production of such alkaline effluents increasing with increasing concentrations of the raw wastes. If a neutral or slightly alkaline reaction (after two days anaerobic storage) be taken as a criterion of safety for discharge into a municipal sewage plant, then satisfactory effluents were obtained with 1 per cent skim milk by filtration through 1 ft., 2 per cent milk through 2 ft., 4 per cent milk through 3 ft. and 7 per cent skim milk required 5 ft. of filtration. Creamery wastes will generally be less concentrated than 4 per cent skim milk; consequently

shallow filters may be employed if the effluent is to be discharged into a municipal sewer.

In designing a plant for a given situation, certain local factors must be taken into consideration. If the effluent is to be discharged into a municipal sewerage system, partial purification to the extent of removing the acid-producing constituents, would be all that should be necessary. If the effluent is to go to a very small stream or dry run, then more complete purification would have to be accomplished. Should this dry run or creek reach a sufficiently large body of water in the course of several miles, partial purification by filtration, coupled with chlorination of the effluent, will be found most feasible and economical.

The waste, before being applied to the filter, must be given preliminary treatment only to the extent of removing grease and settleable solids, and such preliminary treatment must not be prolonged to a point where acidity develops. In practice it will be found necessary to clean the grease-trap and settling tanks frequently to avoid local odor nuisances.

The size of the filter to be employed for any given situation will depend on the necessary degree of purification and the concentration and volume of liquid to be treated. The volume of waste in several of the Iowa butter-making plants has been found to be between 3 and $3^1/_2$ gallons per pound of butter manufactured. A filter 1/100 acre in area and 6 feet deep, if properly constructed and operated, should be sufficient to treat the waste from 1500 pounds of butter per day, if the effluent is to be discharged into a small city sewage disposal plant or a small creek.

Various filling materials have been employed in the experimental filters. These included, (1) lath, (2) coarse rock (2 to $3^1/_2$ inch), (3) gravel, (4) broken tile, (5) cinders, (6) spiral-ring packing, (7) corncobs. The spiral-ring packing proved to be very unsatisfactory; small gravel gave good results but clogged very badly; corncobs effected considerable reductions, but are not considered suitable; broken tile gave good purification but the tile gradually disintegrated and packed badly. Lath, coarse cinders and rock were the most promising filling materials. A typical series of results with these substances is shown in Table V.

It is evident that the cinders were most efficient but it is very questionable whether sufficient suitable material could be found for use on a plant scale. A slightly smaller size rock would probably be most practical though not as efficient. In using coarse materials, such as rock, particular attention should be paid to the cycle of application of the waste or period of rest between doses. A very convenient and perhaps most useful single measure of the purification effected is to determine the biochemical oxygen demand (*i. e.*, the amount of dissolved oxygen the waste or filter effluent will use up if mixed with water). Employing this measure it was found that the dosing cycle markedly influenced the degree of purifi-

TABLE V

PURIFICATION OF MILK WASTES BY TRICKLING FILTERS WITH VARIOUS FILLING MATERIALS

(Applied at 800,000 Gal./Acre/Day for 10–14 Hours Daily)

Sample	Oxygen Consumed	NH_3	Org. N	NO_3	pH*	Relative Stability
	Analyses in P. p. m.					
Applied Waste	398	1.3	51	1.3	6.7	..
Coarse Cinder Effluent	45	0.3	5.7	12.3	7.8	90%
Lath Filter Effluent	87	0.5	10.7	5.2	7.6	85%
Coarse Rock Filter Effluent	120	2.0	27.2	0.5	6.6	40%
	Per Cent Reduction					
Coarse Cinder	88.7	77.0	88.8			
Lath	78.4	61.6	79.0			
Coarse Rock	70.0	..	46.7			

* After storage at 20° C. for 2 days.

cation effected by coarse rock. Thus, a waste with an average B. O. D. of 1100 p. p. m., when applied to a coarse rock filter at a rate of 800,000 gal. / acre / day for 10 to 14 hours daily, but at different dosing cycles, gave the following effluents:

$7\frac{1}{2}$ minute cycle	95 P. p. m. B. O. D.
10 minute cycle	128 P. p. m. B. O. D.
20 minute cycle	229 P. p. m. B. O. D.

With coarse filling materials a short dosing cycle gives the highest degree of purification. Finer filling materials give better results with longer dosing cycles.

Summary and Conclusions

The studies on disposal of creamery wastes demonstrate clearly that:

1. Anaerobic devices, such as septic or Imhoff tanks, are not suitable for the treatment of creamery wastes because,

(*a*) The milk sugar is rapidly decomposed with the production of acids which may curdle the waste. The curd may precipitate or rise to the surface as a scum.

(*b*) If the creamery waste is sufficiently concentrated, the resulting acidity will inhibit the protein-digesting bacteria and many of these proteolytic organisms will be killed. The tank thus becomes a sedimentation tank instead of a biological digestion tank. Curds have been observed which appeared to be practically unaltered after six to nine months in septic tanks.

(*c*) The effluents from such anaerobic tanks, because of their high acidity and, in some instances, suspended curds, are in an undesirable state for most efficient treatment on sand beds or stone filters.

(*d*) The high acidity and consequent relative sterility of the contents of anaerobic tanks receiving sugar wastes result in high relative stabilities of the effluents. These are, however, merely apparent and not true stabilities. They may account, however, for the former recommendations, by agricultural authorities, to employ large septic tanks of at least six-day capacity.

2. Creamery wastes can be rendered innocuous in their effect on municipal sewage disposal plants by being subjected to some form of aerobic treatment.

3. The activated-sludge process is effective for removing acid-forming materials from wastes, but the process is not considered suitable for the average creamery.

4. Trickling filters are particularly adapted to the biological oxidation of acid-forming constituents in creamery wastes.

5. Stable effluents have been obtained by filtration of 1 to 1.5 per cent skim-milk solutions through six feet of cinders at a rate of about 500,000 gallons per acre per day.

6. A short dosing cycle (about 5 to 7 minutes) should give much better results than the commonly employed 15 to 20 minute cycle, when employing coarse filling materials such as 2 to $3^1/_2$ inch rock.

7. Filtration of creamery wastes through 4 feet of coarse cinders ($^3/_4$ to $1^1/_2$ in.) or 6 feet of medium size rock ($1^1/_2$ to $2^1/_2$ in.) at 500,000 gal. per acre per day should produce effluents which will not become appreciably acid and which should therefore not interfere with septic action if admitted to a municipal sewage disposal plant.

8. In certain locations where the effluent runs into a small creek which enters a larger stream in the course of a mile or two, partial purification by filtration, supplemented by chlorination of the effluent, should be most feasible and economical.

9. Preliminary treatment to the extent of removal of grit and fat is essential to the successful operation of the trickling filter. Prolonged detention in preliminary treatment processes is detrimental.

Disposal of Silk Mill Waste at South Manchester, Connecticut*

BY L. H. GEER

With Cheney Brothers, South Manchester, Connecticut

It was about 1880 that Cheney Brothers, silk manufacturers, laid a few pipe lines conveying the wastes from their mills, tenement houses and residences, at South Manchester, Connecticut, to a nearby stream. They gradually extended these lines as the population increased until now there is a system consisting of about 43 miles of street mains, serving a population of over 12,000, a silk-manufacturing plant with about 3200 employees, as well as a paper mill and other smaller industries. The surface water is handled by a separate system.

Sewage treatment was not attempted until 1899 when an intercepting sewer and twelve sand filter beds were constructed, each $^3/_4$ acre in area. These beds were located in a sparsely populated district about two miles from the silk mills and more than a mile from any residential section. In a short time it was demonstrated that continuous operation of these beds was impossible, because the solids in the wastes quickly formed a filter-proof coating over the sand. However, these beds were used as steadily as possible for a period of eighteen years, and were then discontinued, pending further investigation.

During the year 1919 two engineering concerns were consulted. After carrying through analyses and experiments, each advised chemical treatment and settling tanks. One proposed the use of about six tons and the other from three to four tons of chemicals per day. The report of these experiments states that a satisfactory effluent was not obtainable at all times and that it was not considered advisable to undertake such treatment, due to the large quantities of chemicals required.

Considerable time was spent the following year in conjunction with the State Department of Health in an endeavor to develop some method of separating and treating the various concentrated mill wastes, without satisfactory results.

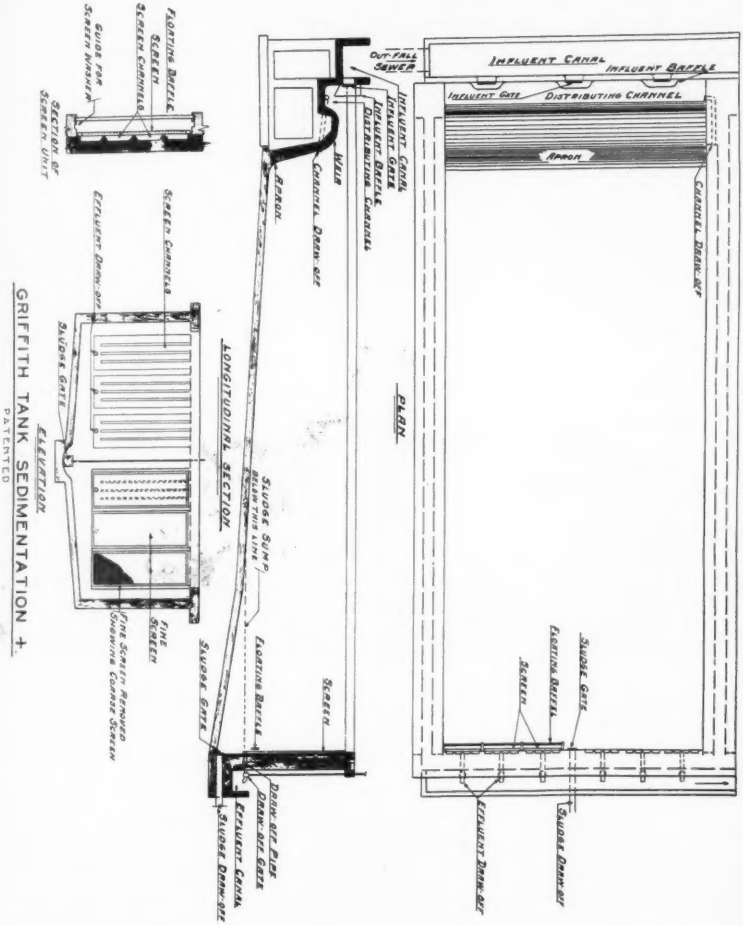
In 1921 an experimental treatment plant was constructed and experiments were again made with chemical precipitation. These experiments were continued for many weeks and the resulting effluent was very good but again the large quantity of chemicals required was an objectionable feature.

In July, 1925, Cheney Brothers began their experiments on clarifying the sewage by quiescent settling and drawing the supernatant liquid

* *Presented before the Third Annual Meeting of the New England Sewage Works Association, Hartford, Conn., April 27, 1931.*

through fine screens, a treatment that had been devised by one of their foremen, Mr. Chas. R. Griffith.

After two years of experimentation and development, under the direction of Mr. Griffith, a 160,000-gallon concrete sedimentation tank, of a rather radical design, was constructed. At the same time a temporary

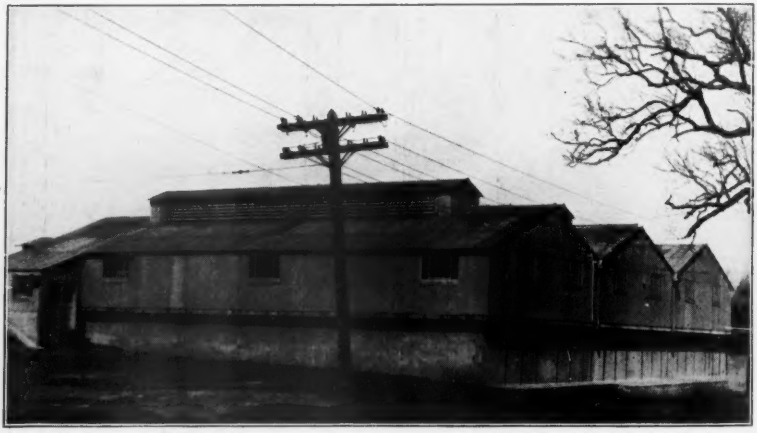


sludge-drying bed was made on the natural sub-soil, which was quite coarse. This tank and sludge-drying bed were placed in service in December, 1927, and were operated practically continuously until September, 1929. During this time, not only were many tests and experiments made,

many of which were in conjunction with the State Department of Health, but also 215,000,000 gallons of sewage were given satisfactory primary treatment.

During the first year of operation there was no roof or housing over the tank and it was observed that the sun, wind and rain were detrimental to the settling and drawing off of the wastes, although the absence of any visible solids in the effluent was quite noticeable. In 1928 the tank was roofed in, which not only improved the settling and drawing but also greatly improved the working conditions. In order to determine how large a quantity of this effluent could be satisfactorily treated by a trickling filter, a small experimental filter was constructed at this time.

During the winter of 1929 and 1930 two similar tanks were added,



Enclosed Treatment Works, Cheney Brothers, South Manchester, Conn.

some alterations made on the first tank and three sludge-drying beds constructed.

The three units were put into service April 2, 1930, and since that time have been able to treat satisfactorily over 90 per cent of the total flow, which total flow is estimated to be about 75 per cent of normal. It is expected that more tanks will be built in the future.

These tanks with their sloping bottom and very fine screens are a modern adaptation of the fill-and-draw type of tank and are known as the "Griffith Sedimentation Tank." With these tanks quiescent settlement and rapid drawing, without disturbing the settled solids, has been obtained.

The three adjoining concrete tanks, each of 160,000-gal. capacity,

are completely housed over with metal siding and roofing on a steel frame. The influent channel is along the front or inlet end of the three tanks with three valved openings into each tank. Directly in front of each opening there is a deflector, and across the front end of each tank is a weir, which allows the influent to flow into the tank uniformly throughout the whole width. Each tank is about 32 ft. wide and 70 ft. long, with an average depth of about 10 ft. The bottom slopes toward the sludge gate, which gate is located in the center and at the bottom of the rear end wall. The upper 12 ft. of the inside face of the rear end wall is practically covered with screens, which are tightly fastened to the wall. There are floating baffles in front of the screens which prevent any floating solids coming in contact with the screens. There are wide channels in the face of the wall behind these screens, and at the bottom of these channels are the valved effluent outlets. These outlets open into the effluent channel which is along the rear end of the tanks.

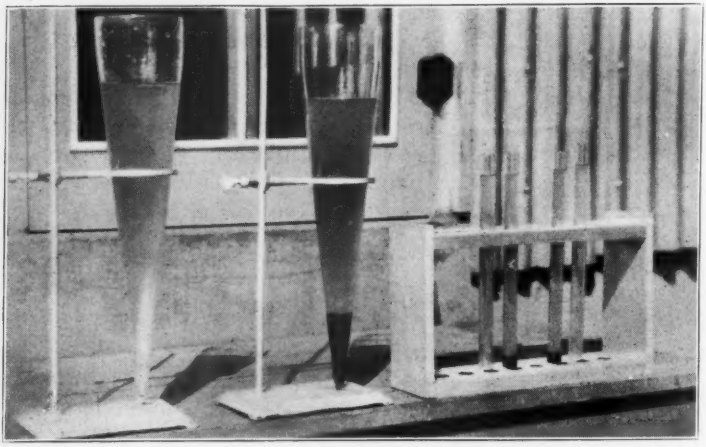
The screens consist of special woven wire cloth, with openings equalling an 80-mesh screen, backed up with a heavy 3-mesh wire cloth, both tightly fastened on a wood frame. These screens are easily cleaned by a downward spray of water thrown on them from a perforated pipe which is raised and lowered in grooves in front of each screen.

As there is no water under pressure near the plant the effluent from the tanks is pumped and used for this spray. The sludge sump is below the bottom of the screens and has a capacity of 1000 cubic feet. A 12-in. cast-iron pipe connects each sludge gate with a sludge-drying bed. These beds are at a lower level so that the sludge flows onto them from the sludge sump by gravity. Each bed is 33 ft. wide and 90 ft. long. They are constructed in the usual manner, with tile under-drains, and 12 inches of screened and washed sand over a 12-in. layer of crushed trap rock. These beds are not glass covered. A half-yard bucket carrier, with hoist, runs on a track which is supported by "A" frames over the longitudinal center of each bed. The track extends outside the sludge bed at one end so that the bucket may be dumped over a truck.

The experimental trickling filter is a 12-ft. square box resting on a grooved concrete slab, filled with $2^1/_2$ in. trap rock to a depth of seven feet. In the center there is one spray nozzle which is piped from a siphon tank. Alongside the trickling filter there is a small secondary settling basin.

The actual operation of the plant is quite simple. The total flow of the waste is directed into one sedimentation tank by the opening of the three inlet valves. When this tank is full, these valves are closed and the flow is directed into the next tank by opening three similar valves. After allowing the first tank of wastes one and one-half hours detention, the quick opening outlet valves are opened, which draw the supernatant

liquid through the screens into the effluent channel and from there it flows to the nearby stream. It requires about 45 minutes to draw the 160,000 gals. from the tank after which the valves are closed and the screens are sprayed clean and the tank is ready for the next filling. This leaves two-thirds of the bottom of the tank covered only with the settled solids and the inrush of the wastes of the next filling washes those solids into the sludge sump. At present, during the time of maximum flow, if the first tank is not empty and ready to be filled by the time that the third tank is full, the total flow is bypassed for a short period. After sufficient sludge is collected in the sludge sump, which ordinarily settles the solids from about 2.5 million gallons of waste per tank, it is drawn



Settleable Solids, Imhoff Cones, Raw and Settled Effluent.

onto the sludge drying beds, along with any scum or floating materials which have collected.

Drawing off the sludge requires about twenty minutes and this is done at night when the flow is small. The complete operation of the tanks requires only one man for about twenty-one hours per day, and is divided into two shifts. Thus, two men operate the tanks and will be able to do so when the plant is enlarged to its ultimate size. As there is no secondary treatment of the sludge at present, bar screens or grit chambers are not required. The time required for dewatering the sludge to 85 per cent moisture content, in which condition it may be handled, has averaged about 60 hours. In this condition it is removed, first placing it in the bucket conveyor with forks, from there into a truck and then carried and dumped either in a pile or on nearby farm lands.

During the last twelve months over 600,000,000 gals. have been treated. The various average quantities are as follows:

Av. Daily	1.67 mg.
Max. Daily	2.56 mg.
Min. Daily	0.51 mg.
Max. Hourly	0.21 mg. or at a rate of 5.0 m. g. d.
Infiltration Daily	0.40 mg.

The large variation is caused by the mill wastes, which compose about two-thirds of the total flow.

There is a considerable amount of oils, soap, chemicals and paper stock in the mill wastes besides the silk gum (sericin) which is boiled off from the raw silk. During the year 1930 the mills used over 78 tons of various oils, 438 tons of gum, 273 tons of soap and 580 tons of dyestuffs and chemicals, a large part of which is discharged into the sewer. Therefore, it can readily be seen that this sewage is strong in oxygen demand and from medium to strong in suspended solids.

The trickling filter has been in continuous operation since April 3, 1930. The rate of filtration from April to August, 1930, was $3^1/_4$ million gallons per acre per day. From August 1 to February 1, 1931, the rate was increased to 4 million gals. per day. From February 1 to April 1 the rate was decreased to $3^1/_3$ million. The rate was increased to $4^3/_4$ million gals. per day April 1, 1931, and the filter is now operating at that rate. The detention period in the secondary settling tank is about 125 minutes at the $3^1/_4$ million rate, about 110 minutes at the 4 million and 90 minutes at the $4^3/_4$ million. There seemed to be practically no difference in results between the $3^1/_4$ and 4 million rate.

The Connecticut State Department of Health has made several reports of their examinations of the sewage entering and leaving the plant, and the laboratory at Cheney Brothers has made weekly analytical determinations for suspended solids, biochemical oxygen demand, and oxygen consumed of the influent and effluent of the sedimentation tanks and the effluent from the experimental trickling filter. At first determinations of settleable solids were made but were discontinued as the results always showed between 99 per cent and 100 per cent removal. The B. O. D. determinations have been made by the dilution method with a five-day incubation period. The following is the average of *all* weekly analyses for the past year in parts per million.

	Suspended Solids	B. O. D.	Oxygen Consumed
Raw Sewage	310	455	201
Tank Effluent	112	287	148
Trickling Filter Effluent	37	45	75

The following is the average of seven sets of analyses at which times there was no mill waste in the sewage (Sunday), in other words, domestic sewage.

	Suspended Solids	B. O. D.	Oxygen Consumed
Raw Sewage	429	359	157
Tank Effluent	90	175	110
Trickling Filter Effluent	37	26	70

We have removed an average of 4.8 cubic yards of sludge from the sludge beds per million gallons of sewage, or a total of 2,880 cubic yards for the year. The moisture content was 85 per cent.

We have found that the pH of the sludge which remains in the tanks for several days changes according to the pH of the incoming sewage.

The ultimate plant as designed will consist of six tanks and six sludge beds, based on the plan that the sludge can be removed in six or seven days. During the last year we have been treating as much sewage as possible in the present tanks and have been able to remove the sludge. It is interesting to note that we have found that the sludge dewaters to a point of handling more quickly in winter than in summer. Many times all the sludge has actually been removed from the bed within forty hours from the time of application.

We have tried to use the old nearby sand beds in a very limited manner, but without success. About 200,000 gal. of sewage was turned onto each $^3/_4$ acre sand bed, once every four or five days. After six fillings the beds were plugged and some liquid was still on the beds after six days from the time of filling.

We find by our analyses that usually the more sludge there is in the tanks, up to a certain limit, the greater the percentage of removal of suspended solids and also, when the mill wastes form a considerable portion of the total wastes, the percentage of removal of the B. O. D. is not in the least parallel to the percentage of removal of suspended solids. Even though the operation of the plant has been very satisfactory, we are continually making various experiments, endeavoring to produce better results and lower operating costs.

Editorial

Journal Now Bi-Monthly

This issue marks a change in issuance from quarterly to bi-monthly. This change was adopted by the Board of Control at the 1932 Annual Meeting, on the recommendation of the Editor.

The articles presented at meetings of the various local associations, together with the contributions submitted directly to the Editor, have become so voluminous that the quarterly issue was becoming somewhat overloaded. Each of the last three journals has contained from 215 to 236 pages, and from 19 to 28 original articles, some of considerable length. Few readers could read and remember even half the articles in one issue, and quite probably most busy readers would take up the JOURNAL several times, read a few articles in it, and then lay it aside. Once laid aside, a periodical is seldom reread, unless some specific information is needed.

With six issues instead of four, it is hoped to reduce the number of articles to from twelve to fifteen per issue, thus relieving the reader of an excessive number of articles in each issue, and increasing the probability that all may be read.

A reduction in the number of articles per issue is not the only advantage in more frequent appearance. Papers can be published more promptly, thus rendering an important service to the authors, who usually are dissatisfied, and justly so, by delays of six to nine months between presentation and publication of their papers. This JOURNAL was at quite a disadvantage in this respect, as compared with weekly or monthly publications in the sewage field, but this disadvantage will now be lessened.

The abstract section can now be kept more up-to-date. It will bring more prompt information concerning progress in sewage disposal in foreign countries. The policy of publishing quite detailed abstracts of foreign articles makes it unnecessary to refer to the original articles, unless the exact words of the author are desired. Articles from American journals are not abstracted in such detail, since the originals are more easily obtainable than the foreign journals.

Another advantage of bi-monthly publication is the more timely notice of coming meetings and of the minutes of completed meetings. This advantage will depend upon the promptness with which such notices or minutes are sent to the Editor by the secretaries of the local associations. Prompt publication would also be aided if the secretaries or editors of the

local associations would forward manuscript as soon as possible after meetings have been held.

These various advantages will add to the cost of producing the JOURNAL, but the subscribers will get the benefits without extra cost. The Federation is indebted to the Chemical Foundation and to our advertisers for the funds that make possible this expansion, at a time when the budgets of many other publications have been reduced. Our readers can help the progress of the JOURNAL by bringing in new subscribers (new members of local associations) and by noting the advertisers and their equipment.

With a balanced budget, more frequent publication and constantly improving quality of contributions, we can look forward to a successful year in spite of the economic situation.

Control of Operation of Activated-Sludge Plants

Economical operation of activated-sludge plants is dependent upon skillful technical control. Operating costs are mainly for labor and power, and most of the power is used for compressing air. Use of an excessive amount of air is wasteful, but the effluent is unsatisfactory if insufficient air is applied. The operator must therefore apply sufficient air to obtain a continuously good effluent, but not so much as to be wasteful. The control of operation must also take account of such other variables as strength of sewage, aeration period, amount and concentration of returned sludge, and rates of settling in the final tanks. Operating routine cannot be based upon mere visual inspection of the condition of the aeration and settling tanks, but must be based upon the results of tests and chemical analyses of the sewage, returned sludge, aerating sludge plus sewage, final effluent and excess sludge.

A noticeable improvement has occurred during the past ten years in the development of analytical and operating tests which furnish a more precise basis for the control of the process. The two major lines of development have been in the direction of tests for determining the minimum amount of air that can be used without endangering uniformly efficient operation, and tests for determining the condition of the sludge. These tests are physical, chemical and biological. The results must be interpreted with judgment and conservatism, and tests which may be invaluable at some plants (for example, on reaerated sludge) may not be applicable at others.

The usual control tests used ten years ago comprised analyses of influent and effluent, with special emphasis on the nitrate content of the effluent, volumetric sludge settling tests, computations of aeration periods and settling rates, and moisture content of excess sludge. Experience has shown that some of these tests should be modified, other eliminated and new ones

devised. Now it is customary to determine suspended solids by weight in the aeration tanks, since it was found that "bulking" of sludge caused results of the volumetric settling test to be quite unreliable at times. The study of "bulking" has indicated that computation and recording of the "sludge index" may be of value for following the changing characteristics of activated sludge, particularly from the standpoint of settleability. (The sludge index is the per cent solids, by weight, multiplied by 100, divided by the per cent settleable solids, by volume. A high index indicates a heavy sludge that should settle quickly, while a low index indicates a fluffy, non-settleable sludge. More data are required from various plants to determine the reliability of this test.)

There still seems to be a considerable variation in the concentration of activated sludge carried in the aeration or reaeration tanks. There has been a trend toward an average concentration of 3000 parts per million in the aeration tanks, but some plants carry as little as 2000, and others as much as 4500 parts per million. Some thought has been given to the computed average displacement period, in days, of the sewage solids in the aeration tanks. With dilute sewage and 4000 p. p.m. or more in the aeration tanks, the theoretical detention period may be as long as 10 or 15 days, while with concentrated sewage and only 2000 p. p.m., the period may be only 3 or 4 days. It is apparent that there will be more aerobic digestion of the organic matter of the solids in the first case than in the second; the sludge will be more completely stabilized; but additional air may be required. For fertilizer production short periods may be desirable, to conserve nitrogen, but for ultimate disposal by digestion longer storage may be advisable. Sludge reaeration provides opportunity for lengthening the total aeration contact period of the sludge, and thus reaeration seems to be of value particularly for concentrated sewage.

The function of reaeration is still somewhat obscure, due to the lack of analytical yardsticks for determination of the results accomplished during reaeration. It would seem that determinations of dissolved oxygen would be of significance, but improved technique is required before even this test can be made with accuracy. Mr. Theriault has been working on this problem (see page 286) and one of Stroganoff's assistants at Moscow has also sought to devise a procedure for eliminating the rapid consumption of oxygen by the sludge, which interferes with the determination (THIS JOURNAL, **3**, 151 (January, 1931).

Additional chemical or biological tests are needed for determining the effect of reaeration and the degree of activation of sludge in the aeration and reaeration tanks. Biological observations have been reported, and there seems to be somewhat general agreement that "bulked" sludge or poorly activated sludge contains a predominance of filamentous forms such as *Sphaerotilus* or *Carchesium*, while well-activated sludge is fairly free from

these organisms and may or may not contain protozoal forms. At present, however, routine biological examinations have not progressed beyond the stage of qualitative tests, and such results are not precise enough to be of much value for plant control.

Analyses of influent and effluent still furnish the criteria for a quantitative measure of results accomplished, with special emphasis on the suspended solids and biochemical oxygen demand. Nitrate production is apparently not so essential for a high degree of treatment by the activated-sludge process as it is for satisfactory operation of trickling filters, consequently the air applied is cut for economy's sake to the lowest amount that will give a uniformly satisfactory removal of B. O. D. The maximum removal of suspended solids is dependent to a large extent on the rates of settling and the design of the effluent troughs in the final settling tanks. It is customary to maintain a "sludge blanket" in mechanically cleaned final settling tanks; a series of small air-lifts, working from various depths, is of assistance to the operator in maintaining the proper depth of "blanket."

Considerable use has been made of centrifuge tests for rapid approximation of the concentration of solids in aeration or settling tanks. Such tests must be frequently re-calibrated against gravimetric determinations, but for plant control the precision seems to be sufficient for practical use.

The greatest need for additional tests seems to be in the direction of measurement of the degree of activation of the sludge, determination of the optimum amount of sludge in the aeration tanks, measurement of the results accomplished by reaeration and determination of the efficiency of utilization of the oxygen applied. Probably in the next ten years, operating tests will be worked out to enable the plant operator to measure these variable factors accurately, so that the plant may be operated at maximum efficiency.

Proceedings of Local Associations

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Hall, Hilliard D.
Marx, George
Morse, S. M.
Rider, Jane H.
Scott, Donald
Travaini, Dario

California Sewage Works Association

Edward A. Reinke, *Secretary-Treasurer*, 101 Civil Engineering Bldg., Berkeley, California

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Albers, J. C.
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Arndt, Charles
Banta, A. Perry
Bartlett, Max C.
Bates, John S.
Batty, Frederic A.
Beale, Ed. W.
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Bell, Alexander
Bennett, S. M.
Berg, Wm. F.
Berryhill, R. M.
Beyer, A. C.
Biggar, L. H.
Bishop, H. N.
Blakely, J. F.
Blood, Chas. R.
Blumberg, Oscar
Bowen, M. R.
Bower, Nobel
Bowlus, Fred D.
Bravender, N. F.
Brown, Robert F.
Buck, J. H.
Burgess, Raymond
Burt, Austin
Byxbee, J. F.
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Clarkson, Jr., Edw. H.
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Cortelyou, H. P.
Crist, Marion L.
Currie, Frank S.
Daley, Albert C.
Darwin, A. Gilbert
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Davies, Jr., Donald
De Costa, J. D.
De Martini, Frank E.
Deming Co., The
Derby, Ray L.
Donaldson, D.
Eastman, T. F.
Ellinger, Morris
Escondido, City of
Fairbanks, Morse & Company

* Note: All members are located in the states of which they are members except as otherwise noted at the end of each local association.

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Ferguson, E. R.
Fittinger, N.
Folsom Sanitary District
Foreman, Merle S.
Foster, Jr., Herbert B.
Foster, William Floyd
Froehde, F. C.
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Central States Sewage Works Association

The Annual Meeting of the Central States Sewage Works Association for 1932 will be held in Rockford, Illinois, on Friday and Saturday, May 13 and 14; with headquarters at Hotel Nelson. There will be joint sessions with the Illinois Association of Sanitary Districts, thereby providing an exceptional opportunity for those attending the meeting to secure friendly exchange of information and experience covering practically the entire field of sewage works practice. Indications are that a diversified program of unusual interest will be presented. One outstanding feature will be the dedication of Rockford's new sewage treatment plant, marking another important step in the cleanup of the Rock River. This modern plant includes much to attract the attention not only of those persons directly interested in sewage treatment, but also of municipal officials and the public in general. Accordingly, a cordial invitation to attend the Rockford meeting is hereby being extended to those officials and all other persons who are in any way interested in municipal sanitation and clean lakes and streams.

GUS RADEBAUGH, *Secretary-Treasurer*

New England Sewage Works Association Annual Meeting

Preliminary Announcement

The Fourth Annual Meeting of the New England Sewage Works Association will be held on April 25, 1932, at the Hotel Bradford, Boston. The morning session will be devoted to papers on "Industrial Wastes in Relation to Sewage Treatment," "The South Essex (Mass.) Sewerage Project," and a description of "The New Sewage Treatment Plant at New Canaan, Conn." Business meeting and election of officers will follow.

The afternoon session will be devoted to Round Table discussion on screens, removal of oil and grease, operation of small treatment plants and separate sludge digestion. The committee on sewage sampling will report.

The annual dinner will be held at the hotel at 6:30 P.M., to be followed by a musical entertainment. The after-dinner speaker will be Prof. John W. M. Bunker of the Dept. of Biology and Public Health of the M. I. T. who will give an illustrated talk on stream pollution and self-purification of streams.

The registration fee will be $2.50 including the dinner. There will be no Association luncheon, but luncheon may be obtained in any one of the three dining rooms of the hotel at prices agreeable to everyone. Registration fee for those not attending the dinner will be $1.00.

As at the last annual meeting, exhibits of sewage treatment plant equipment presented by various manufacturers of such equipment will be on display.

F. WELLINGTON GILCREAS, *Secretary-Treasurer*

Reviews and Abstracts

H. W. STREETER

Operating Data of Treatment Plants in the Ruhr District

By Dr. Ing. Mahr

Tech. Gemeindeblatt, **34** (Sept. 12, 1931)

Abstracted by G. P. Edwards

A study of data from various plants and a comparison of one with another is important for supervision of operation as well as a basis for new plans. Several plants operated by the Ruhrverband are chosen as having similar average conditions.

Mechanical Treatment Plants.—The plants consist mainly of coarse screens, shallow grit chambers, Imhoff tanks and sludge drying beds. Gas is collected at most of the plants but is not turned to profit in all cases. The operating data are shown in Table I. Most of the values are averages of several years.

The cities are predominantly small and average sized, varying from 6000 to 20,000. The estimated populations may not be accurate in all cases as reliable figures are often unobtainable. Screenings are greatest from cities with open sewers such as Velbert. In the Ruhr District an average of 0.035 to 0.071 cu. ft. of screenings is obtained per capita per year.

The amount of grit is fairly constant in small cities, varying somewhat according to the contour of the land and the condition of the streets. In the cities discussed, there is an average of 0.35 to 0.42 cu. ft. of grit per capita per year. In cities such as Witten and Hagen, which are thickly settled and have more paved streets and yards, the amount of grit is smaller, averaging 0.21 cu. ft. per capita per year in Witten and only 0.11 cu. ft. in Hagen.

The digestion chamber capacity varies considerably but the amount of industrial waste and the average sewage temperature must be considered. Due mainly to differences in temperature, the amount of sludge drawn per unit volume of digestion capacity varies considerably. For instance, at Velbert with an average sewage temperature of 11° C., only 1 cu. ft. of sludge per cu. ft. of digestion space per year was drawn whereas at Kettwig, with a temperature of 18° C., nearly three times as much was drawn.

In small cities with predominantly domestic sewage about 0.005 to 0.0074 cu. ft. of liquid digested sludge per capita per day or 1.8 to 2.2 cu. ft. per capita per year is obtained. Cities with large amounts of industrial wastes, such as Kettwig and Kupferdreh, have 0.015 to 0.17 cu. ft. per capita per day. The large amount of sludge obtained at Hagen is remarkable. About 1.48 cu. ft. per capita per year is an average value for dry digested sludge as drawn from the beds. Kettwig and Kupferdreh however have three times this amount. The large amount at Hattingen results from the digestion of excess activated sludge. About 0.175 cu. yd. of dry sludge per sq. ft. of drying beds is removed per year as an average. The plants at Hattingen have a greater drying space per capita so that the drying accomplished per unit area of bed is less.

Plants treating domestic sewage yield about 105 cu. ft. of gas per capita per year. Hattingen produces a little more since the sludge from the submerged contact aerator is included. The high value of 193 at Kettwig is due to the wool-washing wastes.

The data giving the volume of gas produced from 1 cu. ft. of liquid sludge and in 1 cu. ft. of digestion space are interesting. In Velbert, where the digestion period is very long, the gas produced per cubic foot of sludge is large but per cubic foot of digestion space is small. In strongly overloaded plants such as Kettwig and Hattingen, the gas per cubic foot of sludge is about half the Velbert figure and per cubic foot of digestion space, it is two or more times as large. On the whole, about 50 cu. ft. of gas can be expected from 1 cu. ft. of liquid digested sludge. About 100 cu. ft. of gas per year can be obtained from 1 cu. ft. Imhoff tank space with favorable temperature conditions, according to the results at Kettwig.

Biological Treatment Plants.—The operating data of the biological plants is shown in Table II. Rellinghausen and Iserlohn are activated-sludge plants using paddle wheels and compressed air. Hattingen and the old Velbert plant consist of submerged contact aerators for complete treatment in one case and for partial treatment in the other. Two other activated-sludge plants have been added, a small one with Kessener tanks for treatment of slaughter house wastes at Beverwyk (Holland) and a plant equipped with Kremer apparatus at Templin. The 24-hour flow varies considerably at some plants because of excess ground water during storms. The B. O. D. figures are for average sewage flows and are obtained from filtered samples incubated 5 days. The B. O. D. in grams per capita per day at Rellinghausen is about the same as given for American conditions. For the other plants, the value is about half. The average B. O. D. reduction amounts to 0.28 to 0.42 lb. per sq. ft. of aeration tank surface per day.

The rates of air to sewage is about 6:1 in American and English plants, but at Rellinghausen and Iserlohn, where the sludge is kept in suspension

TABLE I

OPERATING RESULTS, SEDIMENTATION PLANTS RUHR DISTRICT

Treatment Plant	Connected Population	Screenings		Grit		Digestion Room Capacity		Average Sewage Temp., ° C.	Amount of Digested Sludge — Liquid		
		Cu. Yd. per Year	Cu. Ft. per Capita per Year	Cu. Yd. per Year	Cu. Ft. per Cap. per Year	Cu. Ft.	Cu. Ft. per Capita		Cu. Yd. per Yr.	Cu. Ft. per Cap. per Yr.	Cu. Ft. per Cap. per Day
1	2	3	4	5	6	7	8	9	10	11	12
Hagen	94,000	65.2	0.018	364	0.106	121,000	1.28	13	19,500**	5.67	0.016
Witten	45,000	156	0.092	352	0.213	.....	..	..	.....	..	...
Langendreer	30,000	26	0.025	92.3	0.085	34,200	1.14	13	1,980	1.81	0.005
Kupferdreh	20,000	22.1	0.028	299	0.407	25,800	1.29	14	4,000	5.46	0.015
Velbert	18,000	71.5	0.106	299	0.455	37,000	2.06	11	1,380	2.09	0.006
Hattingen	17,000	52	0.085	222	0.355	15,900	0.94	15	2,960	4.75	0.013
Dahlhausen	7,000	10.4	0.039	117	0.457	8,830	1.26	12	560	2.24	0.006
Kettwig	6,300	11.7	0.053	69	0.298	11,650	1.84	18	1,440	6.25	0.017
Neheim	6,000*	...	...	97.5	0.444	17,650	2.94	11	390	1.77	0.005
Wetter	6,000	20.8	0.096	120	0.532	8,470	1.41	11	385	1.74	0.005
Hattingen-Ost	2,000	...	...	...	...	2,640	1.32	16	247	3.36	0.009

Treatment Plant	Dried			Drying Capacity			Gas			
	Cu. Yd. per Yr.	Cu. Ft. per Cap. per Year	Decrease in Cu. Yd.	Sq. Ft.	Sq. Ft. per Capita	Cu. Yd. Dry Sludge per Yr. per Sq. Ft. Drying Beds	Cu. Ft. per Year	Cu. Ft. per Capita per Year	Cu. Ft. per Cu. Ft. Liquid Sludge 19:10	Cu. Ft. Digestion Space, 19:7
	13	14	15	16	17	18	19	20	21	22
Hagen	..	..	..	....	..	...	.....	..	..	..
Witten	..	..	..	....	..	...	.....	..	..	..
Langendreer	..	..	..	....	..	...	.....	..	..	..
Kupferdreh	3000	4.07	0.75	6,000	0.30	0.50	.....	..	..	..
Velbert	990	1.49	0.72	5,700	0.32	0.174	1,820,000	101	49	49
Hattingen	1560	2.76	0.58	16,100	0.95	0.097	2,043,000	120	25	129
Dahlhausen	..	..	..	....	..	...	.....	..	..	..
Kettwig	1040	4.5	0.72	5,100	0.81	0.202	1,213,000	193	31	103
Neheim	273	1.24	0.70	6,000	1.00	0.045	551,000	92	52	31
Wetter	246	1.1	0.64	1,550	0.26	0.159	600,000	100	57	71
Hattingen-Ost	112	1.53	0.45	1,600	0.80	0.70	.....	..	..	..

* Estimated—the value increases constantly. ** Not accurately measured.

TABLE II

OPERATING RESULTS, BIOLOGICAL PLANTS, RUHR DISTRICT

Treatment Plant	Population Included	Sewage Flow Gal. per Day	Biochemical Oxygen Demand: Influent, P. p. m.	Biochemical Oxygen Demand: Effluent P. p. m.	Biochemical Oxygen Demand: Per Cap. per Day $\frac{3 \times 4}{2}$ Grams	Water Surface of Aeration Tanks, Sq. Ft.	Reduction in B. O. D.: P. p. m. 4–5	Reduction in B. O. D. Per Unit Area $\frac{8 \times 3}{7}$ Lb./Sq. Ft./Day
1	2	3	4	5	6	7	8	9
Rellinghausen	55,000	7,910,000	120	20	65	12,900	100	0.51
Iserlohn*	19,000	791,000	220	50	35	3,760	170	0.30
Hattingen	17,000	660,000	225	70	33	2,020	155	0.42
Velbert-Tauch körper	18,000	660,000	220	150	31	1,076	70	0.36
Velbert-Kessener	20,000	660,000	240	80	30	2,690	160	0.33
Beverwyk** Slaughter House	....	5,660	2000	..	..	344	2000	0.27
Templin	10,000	264,200	300?	100?	30	1,810	about 200	0.24

Treatment Plant	Compressed Air Added: Cu. Ft. per Hour	Compressed Air Added: Cu. Ft. per Day	Air per Sewage: Amount 11/3	Air per Sewage: Surface 10/7 Cu. Ft. per Min. per Sq. Ft.	Oxygen Absorbed: Per Cu. Ft. Air. Lb.	Oxygen Absorbed Per Unit Area $\frac{14 \times 11}{7}$ Lb. per Sq. Ft. per Day	Power Requirements: Total H. P.	Power Requirements: Per 1000 Inhabitants H. P.	Power Requirements: Per Million Gallons, H. P.	Per Ton B. O. D. Reduction H. P.
	10	11	12	13	14	15	16	17	18	19
Rellinghausen	31,770	776,000	0.7:1	0.04	30% = 0.0056	0.336	47	0.85	5.8	14.6
Iserlohn*	12,350	247,000	2.3:1	0.05	0.0050	0.328	18.8	0.99	23.8	33.0
Hattingen	42,360	1,023,700	11 :1	0.36	4% = 0.0007	0.380	32.2	1.90	48.8	75.6
Velbert-Tauch körper	12,700	176,500	2 :1	0.20	7% = 0.0012	0.205	12.1	0.67	18.5	62.2
Velbert-Kessener	....	.....	....	...	.....	...	6.7	0.34	10.1	14.6
Beverwyk** Slaughter House	....	.....	....	...	.....	...	0.81	...	143.1	15.9
Templin	....	.....	....	...	.....	...	8.85	0.89	33.5	40.2

* In comparing Columns 12 and 19 it may be seen that the sewage from Iserlohn is much harder to treat than that from Rellinghausen.

** Sewage flow (39,630 gal. per week) only on five days.

with paddle wheels, the proportion of air to sewage is much less, 2:1 at Iserlohn (heavy, often septic sewage) and less than 1:1 for Rellinghausen. For small submerged contact aerators with an inferior partial treatment such as Velbert, the ratio is 2:1 and at Hattingen for complete treatment the proportion of air is much larger.

A comparison of the amounts of air and sewage is justified only if the air is used for biological purposes and not if the air does part of the mechanical work. At Rellinghausen and Iserlohn 0.04 to 0.06 cu. ft. of air are used per sq. ft. of aeration tank surface per minute. Activated-sludge plants without stirring apparatus use about 0.2 cu. ft. per minute per sq. ft. Hattingen (submerged contact aerators) uses 0.36 cu. ft. Under optimum conditions, about 30 per cent of the air added is absorbed. In submerged contact aerators and activated-sludge plants without stirring, only 4 to 8 per cent is used. These values need not agree with the figures for the decrease in oxygen demand. In general, the amount of oxygen added is less than the calculated reduction in oxygen demand since the solids which separate out are not completely oxidized but are removed as excess sludge.

In activated-sludge plants, more than a hundred times as much oxygen is absorbed per unit area as in natural streams. Streams must oxidize the insoluble solids, whereas they are removed from a treatment plant.

The power required seems to average about 0.94 hp. per 1000 inhabitants. Based on flows, the power varies considerably. A comparison of power required with the sewage flow does not take into consideration the strength of the sewage. When the power is compared with the reduction in B. O. D. a surprising picture is obtained. Rellinghausen and Beverwyk, the opposite in type and quantity of sewage, show almost equal values. One of the advantages of the Kessener tanks depends upon the large amount of returned liquor. Whereas in other activated-sludge plants 15–20 per cent, including the sludge is returned, in Beverwyk about three times the sewage flow is returned and the influent is diluted with water containing oxygen. The power needed for submerged contact aerators is about 3 to 5 times as much as for typical activated-sludge plants. It is advantageous to return large amounts of liquor. This does not actually shorten the net detention period, since a larger proportion of the sewage flow is continuously recirculated. The total contact period is in effect independent of the amount of sludge returned.

The Annual Report of the Ruhrverband, 1931

BY DR. KARL IMHOFF

ABSTRACTED BY G. P. EDWARDS

The Ruhr River water was cleaner in 1931 than for a long time due to greater dilution and the decrease in industrial pollution Because of the

economic condition, about one-third less water was taken from the Ruhr in 1931 than in 1929.

The water-sewage cycle, which is important in the Ruhr during dry years, was studied. Active carbon was used successfully in removing phenol from charcoal industry wastes. Studies were also made of sulphuric acid corrosion, removal of copper from sewage, and the salt dilution method for the accurate determination of quantities of water.

The Ruhrverband is returning in sewage treatment plants to the simplest natural processes such as artificial lakes, earthen tanks, underdrained settling tanks and artificial ponds. These ponds have been especially satisfactory in the Ölbach district and on the Oese for the treatment of mixed domestic sewage and industrial waste. A new treatment plant at Plettenberg, consisting of the simplest type of settling tank, brings the number of sewage treatment plants operated by the Ruhrverband to 70.

A large storm-water tank is being built at Lüdenscheid-Friedrichstal and a field lying near the Arnsberg-Neustadt treatment plant has been prepared as a storm-water tank. A secondary digestion tank has been added at Hattingen.

At Hagen, the overloaded Imhoff tanks were relieved of part of their load with little cost by using a storm-water tank as a secondary settling tank for dry weather flow. The detention period was thus increased from one to two hours and the suspended matter of the effluent was reduced to a sixth. The new settling tank is removed from operation every fifth day. The supernatant liquor is drawn off and the sludge is pumped to Imhoff tanks. Because of the flat bottom, it is necessary to clean the tanks by hand. Five or six hours is required for cleaning. The same process is employed at the Lüdenscheid-Friedrichstal and Lüdenscheid-Elspetal plants. At plants such as Essen-Steele, Essen-Kupferdreh, Essen-Rellinghausen, Hattingen and Langendreer where abundant free land is available, the sludge drying beds are not used temporarily and the digested sludge is pumped directly on the land. At other plants such as Blankenstein-West, Welper and Dahlhausen, the liquid digested sludge is carried away. Since the amount of gas obtained from sludge digestion at Menden and Velbert was not sufficient to produce power for the sewage pumps as well as for the power and air needed by the biological treatment, the night flow is not treated biologically but only settled in the storm-water tanks.

During the year, only about 6.25 miles of sewers were built. Costs of pumping were higher because of the heavy rainfall. A new pumping station was built and put into operation in Bommern.

The operation of Hengsteysee has been very satisfactory both in regard to water purification and power use. The Harkortsee was filled for the

first time in January, 1931, and has been in operation continuously since April. Both lakes have been satisfactory for purification of the Ruhr. Most of the iron sludge settles in Hengsteysee and biological purification takes place in Harkortsee. Construction of Baldeneysee was begun in May.

Construction during the next year will be very limited due to the lack of capital. Only such work as is urgent, and can be done with the unemployed and with little capital, can be done.

Report of the Director of Water Pollution Research for the Year Ended 30th June, 1931. Department of Scientific and Industrial Research, Great Britain

REVIEWED BY H. W. STREETER

The latest report of the Director, Dr. H. T. Calvert, is prefaced by a report of the Board in which the general situation in the British Isles with respect to water pollution and conservation is summed up by the statement that "the available sources, both surface and underground, of unpolluted water are being gradually depleted and there is no doubt that many rivers which are at present to some extent polluted will have to be utilized in the future as sources of supply, after treatment, for both domestic and industrial purposes." The present report evidences the very substantial progress made by the Board, since its appointment in 1927, in carrying out the various technical studies of the problems which have been the main objectives of its work.

Investigations carried forward during the past year have included the continuation of experiments on the treatment of beet sugar waste, a survey of pollution of the River Tees and a further study of the base-exchange, or zeolite, process of water softening. Arrangements for an investigation of colloids in sewage and in beet sugar effluents, made last year, were deferred until satisfactory methods of sampling and analysis had been devised. This part of the work is now completed and the main portion of the investigation is in progress. In connection with the investigation of the corrosive and plumbo-solvent action of certain waters and on methods of corrective treatment, preliminary work, including preparation of a summary of existing knowledge of the subject, is going forward.

Beet Sugar Effluent

In the first (1928) report of the Board, it was pointed out that the ideal solution of the problem of disposing of beet sugar wastes would be so to

alter the manufacturing processes that the waste waters could be re-used and not discharged. Although this plan has been followed successfully by several factories on the Board's recommendation, it has been realized that it might be necessary, in some circumstances, to purify a portion of the waste waters so that they might be discharged into a stream.

Preliminary laboratory experiments having indicated that biological oxidation on percolating filters offered the greatest promise of success, the investigation of this process was undertaken on a semi-plant scale, two circular filters, each 25 ft. diameter and 6 ft. deep, and two rectangular filters, each 3 ft. square and 6 ft. deep, having been erected at the beet sugar factory at Colwich, near Nottingham.

It has been shown by the experiments that a degree of purification of the order of 90 per cent, for press water, the most polluting of the effluents, can be obtained by means of such filters. The flora and fauna of the filters have been allowed to develop naturally and more than 800 pure cultures of bacteria have been isolated from the filters with a view to selecting and inoculating the filters with the strains most active in oxidation of the substances present in beet sugar wastes.

It has been observed in the early experiments that the fresh pulp press liquor is usually alkaline, with pH 7.5 to 8.0. On standing, these liquids ferment rapidly, with sucrose converted to lactic, acetic and other organic acids and the pH falls to 3.0 and 5.0 in less than 24 hours. The effects of adding nitrogen as albumen and as an ammonium salt have been examined. The results have indicated that partial conversion of sucrose into acid products assists biological oxidation in the filter.

As it appeared probable that the oxidation of sucrose took place in stages, experiments have been made in the treatment of solutions of the constituents above named on a filter divided horizontally into six sections, arranged so that samples of effluent and biological film could be examined from each section. The filter was supplied, at the rate of 100 gals. per day per cu. yd. of filtering material, with a solution containing 0.1 per cent of sucrose and sufficient ammonium chloride to provide a ratio of carbon to nitrogen of about 10 to 1. Almost complete oxidation of the sucrose occurred after equilibrium has been established, 40 per cent being removed in the first section, 25 per cent in the second, and, in the remaining four sections, 12, 10, 7 and 6 per cent, respectively. On interchanging the sections, no pronounced effect occurred, once the filter was properly matured; there were indications, in fact, that interchange among the upper sections was beneficial. The oxidation of nitrogen occurred mainly in the lower sections, nitrite and nitrate being produced.

In a filter used for the treatment of a solution of sucrose, the protozoa *Colpidium* and *Bodo saltans* were found in greater numbers in the upper sections and *Euplotes*, *Cinetochilum*, *Pleuronema* and *Podophyra* in the

lower sections. *Paramoecium* was distributed throughout the filter. *Euplotes*, *Cinetochilum* and *Pleuronema*, which feed on organic débris, small organisms and bacteria, could have obtained a more adequate food supply in the upper sections of the filter; likewise *Podophyra*, whose principal food is other ciliates. It thus appears that these organisms require an environment relatively free from soluble organic compounds. On the other hand, it is uncertain whether *Colpidium*, which feeds almost exclusively on bacteria, could find sufficient food in the lower section of the filter where the bacterial numbers must be small. Although the changes in pH found in the filters were within the limits of tolerance of a majority of the organisms, there seemed to be a definite correlation, in a few cases, between the pH value of the liquid and the occurrence of certain species. An acid medium is preferable for *Colpidium* and *Bodo saltans* but not for *Pleuronema*, whereas *Paramoecium putrinum* is not affected by changes in pH from 4.5 to 7.6.

It is generally assumed that the oxidation of solutions of sugar and similar substances in a percolating filter is carried out mainly by bacteria, which have been shown to be very high in the filters studied. The results have already led to the conclusion that certain organisms are of special value for the biological purification of beet sugar effluents. Arrangements have been made for larger-scale experiments on a factory effluent in filters inoculated with selected organisms.

Survey of the River Tees

A biological, chemical and hydrographical survey of the River Tees was undertaken in 1929, with a view to obtaining more precise data concerning the self-purification of a typical stream flowing through an industrial area. The program of hydrographical work has been completed and the results obtained have been published in a separate report (see THIS JOURNAL, **4,** 217 (Jan., 1932)). The main conclusion reached was that, in a tidal river of this kind, polluting matter cannot escape seaward easily except in the surface layer of fresher water.

Biological and Chemical: Tidal Reach.—A thorough survey of the animals and plants living on the river bottom and between tide marks showed numerous and widely varying species at the seaward end of the estuary. Above the influence of salt water, the flora and fauna are normal for a fresh-water stream. As the central zone is approached, from either end, the number of species rapidly diminishes and for a few miles the only permanent organisms are a few species of mud worms, some smaller algae and patches of stunted brown seaweed, *Fucus oesiculosis*. This central zone is subject to the greatest changes in salinity as the water ebbs and flows with the tide. It also is subject to the greatest pollution and lower oxygen concentration.

A survey of the unpolluted estuary of the Tay indicated that in spite of physical differences in the channel bed, the distribution of animals and plants was strikingly similar in the two estuaries; hence the scarcity of life in the central portion of the Tees estuary cannot be attributed solely to pollution.

During the spring of 1930 great numbers of smolts, both salmon and sea trout, died in the upper part of the Tees estuary, in water 70–73 per cent saturated with oxygen. As trout have been kept alive several days in water only 60 per cent saturated, the death of smolts cannot be due to oxygen shortage alone. Chemical analysis of the water showed the presence of tar acids and cyanides, the latter in concentrations found experimentally to be lethal to smolts.

The distribution of toxic substances in the Tees estuary depends not only on the rate at which they are discharged and carried toward the sea, but also on the rate at which they are broken down by bacterial and chemical action in the water. The course of this decomposition is being studied and experiments are being made on the rate of decrease of toxicity toward trout of various effluents when diluted with estuary water and stored.

Experiments have been made to determine the rate at which dissolved oxygen is absorbed by separate and mixed effluents when diluted with water of varying composition, and incubated at summer temperature. The results indicate that the rate of deoxygenation depends not only on the nature of the effluent, but on the salinity and bacterial content of the water with which it is mixed.

Biological and Chemical: Non-tidal Reach.—In May, 1930, 12 monthly surveys at 16 stations had been completed. The monthly surveys were then discontinued, to allow time for the study of special problems, attention being directed particularly to: (*a*) the process of breakdown of sewage and the self-purification of the river after receiving the polluted waters of the Skerne, (*b*) the decolorization of peaty river water, (*c*) the diurnal changes in the nature of the water, (*d*) the seasonal changes in plants and animals, (*e*) the collection of data on the food of fishes and (*f*) surveys of the Skerne.

Observations of diurnal changes in the river have shown that there is more decomposition of sewage during the night than in the daytime.

The plants of greatest importance in the non-tidal reach are the microscopic forms. If glass slides are put down on the river bed, they quickly become covered with minute plants. Similar growths cover every stone, stick and plant in the river. These organisms have been little studied, but are of great importance, as they are the chief food for the animals of the stream. They also play a large part in the oxygenation of the water, especially in the lower layers.

The investigations of the animal life of the stream confirm the previous results. From April to June, inclusive, insect larvae are abundant in the river, then diminishing in numbers and being very few throughout the winter. From studies of the food of various fishes, it is concluded that the trout seems to be definitely carnivorous and the dace and chub, omnivorous.

Activated-Sludge Process

The object of this investigation is to obtain information on the biological changes occurring during the treatment of sewage by the activated-sludge process. For this purpose, a glass aeration tank of 10-gal. capacity has been used, in which samples of sewage from the Croydon works have been treated.

The progressive fall in the counts for both total and viable bacteria indicates that there is no killing of bacteria but an adsorption of them by the flocs. With the decreases in bacteria are also reductions in the 5-day B. O. D. and in the 4-hour permanganate absorbed value. Experiments have been made to determine the part played by bacteria in the B. O. D. test, which has been applied to crude sewage and to sewage treated with chloroform, toluene and other chemical agents, by heating and by centrifuging.

Municipal Engineering in 1931; Sewage Disposal

ANON

The Surveyor, **81**, 105–110 (Jan. 29, 1932)

ABSTRACTED BY J. K. HOSKINS

This article is in itself a comprehensive abstract of the 1931 literature on the subject of sewage disposal. The published information dealing with technical developments of the subject has been extensive but, as heretofore, construction is hesitant to take advantage of this available knowledge, as evidenced in many of the newer works.

Need for Legislation.—Although the Royal Commission on Sewage Disposal completed its labors in 1915 and recommended the enactment of definite legislation to better regulate sewage disposal and stream pollution, no such steps have been taken. This laxity has resulted in much unnecessary work and useless expenditure of funds. Thus Mr. J. H. Garner, Chief Inspector of the West Riding of Yorkshire Rivers Board, has pointed out the failure to enact legislation concerning the admission of trade refuse to sewers. Mr. Sanford Fawcett, late Chief Engineer of the Ministry of Health, noted that the discharge of crude sewage in streams

providing sufficient dilution has not yet been legalized. Both such procedures were recommended by the Royal Commission. There is a strong feeling that the Rivers Pollution Prevention Act should be repealed and the law amended as recommended by all competent authorities and committees.

Methods of Disposal.—Engineers would not hesitate to take advantage of new discoveries in the art if they were not hedged about by legal and other restrictions. Although the process of sludge digestion was known 26 years ago, practised successfully in Birmingham for 17 years and adopted in America and Germany, little further progress has been made until recently in Great Britain. Also, although the possibilities of gas production from sludge were known as early as 1921, not until recently has serious attention been given the matter. The Ministry of Health is perhaps too conservative in its retention of well-tried procedures in preference to new and more economic methods and devices. Thus such a departure from established practice as the Dearborn, Michigan, plant would be impossible in England because of restrictions on the designing engineer.

Sewage Treatment and Sludge Disposal.—Sludge digestion has been demonstrated as of general application, especially for inland towns where odor control and nuisance elimination are essential. Final disposal may be either use as manure or dumping at sea; incineration does not appear generally applicable. Birmingham has the oldest and largest sludge-digestion plant in the world, dealing successfully with sludge from over a million people. An extension of this method to another district of the city is now under construction, including utilization of gas. However, digestion is not universally applicable. At Bradford, where the sewage contains excessive amounts of wool scouring wastes, the sludge, including finer grit, paper and solid matters, is treated with sulphuric acid, the precipitated matter heated and pressed and the grease recovered. The press cake does not become septic or objectionable.

German Practice.—"Dr. Prüss has recently modified his original procedure (of sludge digestion), *viz.*, that of mixing the old digested sludge with the new incoming sludge, by stirring the upper two-thirds of the contents of the digestion chamber, leaving the lower third undisturbed." By drawing off the digested sludge from the bottom of the tank daily the accumulation of worked out sludge is prevented.

American Practice.—The Los Angeles experiments of drawing off at once the inorganic solids which settle to the bottom of the tank promises to receive wide attention and should reduce tank capacity. Such solids are passed ahead with ripened sludge to the next tank of the series. The lighter solids which contain most of the volatile matter thus receive longer detention periods. The experiments of Keefer and Kratz at Baltimore

indicate that, for seeding purposes, there is no great difference in sludges in different stages of digestion, provided the pH value is maintained at about 7.0 to 7.2. These authors infer that the pH value may be the governing factor in the seeding rather than age of the digesting sludge itself and consequently that such seeding with partly digested sludge may be unnecessary. However, at Reading, experiments on a large scale of adjusting the pH in the crude sludge by lime were not successful in the development of an odorless sludge in four months.

Recent Practice.—At Dagenham, for economic reasons, the proposed methods of sludge digestion were modified by reducing the digestion capacity from 2 to $1^1/_2$ cubic feet per capita, or even less, if partial digestion suffices. The Dorr Company considers 1.5 cubic feet proper and Prüss usually provides 1.2 cubic feet. The digested sludge at Dagenham will be dried in lagoons if possible, or if not, will be passed to secondary digestion tanks with earthen banks similar to those at Birmingham. Whitehead and O'Shaughnessy have called attention to the necessity of considering the water content in experiments of sludge digestion and the desirability of making such observations to accompany those of the effect of temperature and reaction. There is also a distinction between the optimum temperature for gas production and for digestion. High temperature digestion, while interesting, is not entirely convincing, because of the limited experimental evidence. Heating will expedite the digestion process and is most effective in the early stages, as has been demonstrated at Birmingham. If two stages of digestion are employed, the second stage may be conducted without heat. Imhoff has shown that the first-stage tank sludge, if heated and stirred, will operate satisfactorily with additions of crude sludge of 6.5 per cent per day of the tank capacity.

Gas Production and Utilization.—Ordinary sewage sludge will produce power at the rate of 1 hp. per 1000 contributing population, but if activated sludge is mixed with the crude sludge this power will be doubled. Gavett, at Rockville Center, New York, obtained 1 cubic foot of gas per capita daily by this mixing process, the gas being used for sludge heating in winter. Recently installed gas engines have generated 2.2 hp. per 1000 population, the cooling water being sufficient for sludge heating. Whitehead and O'Shaughnessy obtained 145 cubic feet of gas per capita from the primary digestion, which is about two-thirds of the total yield, in all stages including drying fields.

Danger of Explosions.—The Woonsocket, Rhode Island, tank explosion is discussed, illustrating the danger of ignition of combustible gases in digestion tanks either through carelessness or by accidental generation of sparks.

Industrial Sewage.—At Shipley, Yorkshire, all of the industrial waste is treated in the central plant, including much wool scouring waste

and all the spent gas liquor from the City of Bradford, which latter amounts to as much as 2 per cent of the total flow. The sewage is first settled in plain sedimentation tanks, chemical precipitation with alum and sulphuric acid having been discontinued. The effluent, admittedly not an ideal one, is then treated on sprinkling filters at the rate of 68 gallons per cubic yard per day. The filters, composed of limestone and clinker, mature slowly but oxidation and nitrification, once established, can be maintained. The wool scouring liquor of the Baildon Combing Company is concentrated by evaporation, grease separated by centrifuging, and the excess liquor treated by a rotary calcinator for recovery of the potash, thereby eliminating completely all liquid discharge from the plant.

The Bradford disposal works at Esholt have recently been completed at a cost of $10,000,000. This sewage, amounting to 18 m. g. d., is about half industrial waste, a large proportion of the latter originating in the woolen industry. Coal is used as the filtering material, which has proved to be serviceable and durable, and because it maintains its calorific value, is a real asset in times of emergency. The recovered grease is marketed, as well as the pressed sludge cake.

Partial purification by the activated-sludge process has proved advantageous at Reading (England). This is also true at Birmingham and Coventry, resulting in reduced operating costs when followed by percolating filters.

Valuable Practical Advice.—Normanton has described the new plant at Sowerby Bridge where the settled sewage is treated by the "Simplex" method. Full details are given of the methods employed for construction of deep conical tanks in wet ground. The method of disposal of sewage of the mining district of Royston is typical of works of this nature where screening, sedimentation, filtration and secondary sedimentation are employed, The West Riding of Yorkshire Rivers Board has advised the re-use of waste waters in a beet sugar factory rather than treatment in disposal works, a procedure that has proved of practical value. Elimination of the fly nuisance at disposal works has received considerable attention. Creosote oil emulsion was effective at Huddersfield; chlorine at Barnsley and in America. Chlorine has also been found helpful in the activated-sludge process, and in increasing the capacity of filters when added to the tank effluent.

Management.—The Ministry of Health is admonished to pay more attention to management of disposal works. There is difference of opinion as to the advisability of employing one manager for several small plants. Besselievre reviewed the question of management in both England and America and stated that the larger American cities are adopting the activated-sludge principle, sludge digestion, gas utilization, sludge filtration and incineration. Improvements in the appearance of disposal works

areas are noted. Automatic working of sewage treatment plants is exemplified in the Santa Barbara County Hospital installation.

Sludge Filters.—Skinner discusses sludge filters in New York State, from which it appears that the area provided there is 0.4 sq. ft. or less per capita. Ten dosings per year of Imhoff tank sludge, each 10 inches deep, can be handled. If covered, the capacity of such beds can be more than doubled but the cost is twice as great. Temple has demonstrated by large-scale experiments in India that the sale of fertilizer from the activated-sludge process there will produce sufficient revenue to pay for the construction and operation of the plants, because of the great demand for artificial manure.

The use of the effluent of sedimentation tanks of large institutions for overhead irrigation has been successful in Germany. The repeated re-use of purified sewage for drinking water has been suggested by Imhoff, who pointed out that the use of polluted river water is frequently a demonstration of this procedure. No relaxation in stream pollution prevention and water purification measures, however, should be permitted.

Sludge Digestion as Applied at the Chorley Sewage Works

BY J. SLATER

The Surveyor, **81**, 200 (February 5, 1932)
(Presented at the Manchester District meeting of the Association of Managers of Sewage Disposal Works, January 23, 1932.)

ABSTRACTED BY J. K. HOSKINS

Sludge digestion without artificial heating or gas collection has been practised for six years at the Chorley sewage treatment works, superseding the former method of sludge pressing. There are six digestion tanks with a total capacity of five months' supply. The drying area is 1 sq. yd. per $4^1/_2$ persons contributing sewage.

The digestion process was started with sludge obtained from a sedimentation tank operated for several months as a septic tank. Following experiments with single-stage digestion, the plan now followed is to use four tanks for primary digestion and two for secondary treatment. The supernatant liquid is decanted to a depth of two feet and delivered directly to the percolating filters and has caused an unsatisfactory effluent, in addition to choking the filters. This liquid should preferably be returned to the influent sewage. Because of the absence of storm overflows and consequent wide fluctuations in storm-water flows much grit and detritus are carried into the sedimentation tanks and then to the digestion tanks.

Ripe sludge is delivered by a centrifugal pump from any desired digestion

tank for mixing with the entering fresh sludge. The efficiency of the pump was reduced by sludge gas collecting in the impeller chamber but this difficulty was overcome by removing the gas with an ordinary, hand-operated diaphragm pump. Short circuiting through the digestion tanks results from provision of a single sludge inlet.

During a period of four years an average of 50 per cent reduction by weight of sludge was obtained in the digestion tanks, some of which, however, is represented by the decanted supernatant liquid. The moisture content is reduced from 90–93 per cent to 85–88 per cent. The weight is further reduced on the drying beds to about 30 per cent of the digested sludge. No aerial nuisance is occasioned in the digestion or drying process.

The humus sludge, of high water content, is returned to the incoming sewage channel thereby obtaining such benefit as there is of adding humus to the sewage to be treated.

Digested sludge is placed on the drying beds to a depth of 16–18 inches in summer and 12–14 inches in winter, which, when dried, is about half this depth. The dried sludge is inodorous, almost free from weed seeds and grease and more suitable for land than pressed cake with the exception of lack of lime. All the dried sludge for the past five years has been sold to farmers. A saving of 50 per cent has been effected as compared with the cost of sludge pressing.

In the discussion of this paper Mr. A. R. Ward pointed out the value of sludge digestion in prevention of aerial nuisance. At his plant (Stockport) sludge disposal for part of the material had been inaugurated to combat odors. A reduction of 10 per cent in organic matter was being obtained in the primary tank and a further 10 per cent in the secondary tank. Recovery of gas was not practised.

Mr. D. Ledson had tried sludge digestion experimentally at Leigh and found that the grease content was reduced and drying quality improved. Disposal of crude sludge on land and plowing in was resulting in drying difficulties.

Mr. W. T. Lockett of Manchester remarked that sludge digestion was coming into more general use in America and Germany than in England and approved the application of the two-stage process as practised at Chorley. He questioned whether a sludge with minimum of mineral matter digested best although for gas production high organic content was desirable. For drainage some mineral matter was helpful.

In reply to various questions Mr. Slater stated the digestion tanks were each 60 × 80 feet by 6 to 8 feet deep. No pH determination had been made on the digesting sludge. The digestion rate was affected by changes in temperature and it had been determined that a maximum efficiency was obtained at a certain temperature (not stated). No serious aerial nuisance was created at any season of the year.

Treatment of Ammoniacal Liquor from Gasworks

BY J. SLATER

The Surveyor, **81**, 199 (Feb. 5, 1932)

ABSTRACTED BY J. K. HOSKINS

This article is an abstract of a paper read at the Manchester District meeting of the Association of Managers of Sewage Disposal Works on January 23, 1932, and discusses the method of treatment of waste gas liquor employed at the Chorley sewage treatment plant.

Although it is stated that as high as 2 per cent of the dry weather sewage flow may consist of gas liquor and not interfere with treatment processes, much depends on the even distribution of this waste throughout the total sewage volume. Such distribution frequently is difficult to obtain in which case as little as $^1/_2$ of one per cent may disrupt the biological treatment process. The discharge of the hot liquor to the sewer aggravates the problem.

Such irregularity of gas liquor contribution to the sewage was experienced at the Chorley plant, thereby requiring special provisions for its treatment. The periodic daily discharge of liquor is diluted with sewage and the mixture stored in a settling tank from which it is applied to old sand filters. This filter effluent is then added to the entire sewage tank effluent and applied to the percolating filters. The raw liquor has an average strength of from 8000 to 12,000 p. p. m. as measured by the four-hour oxygen-absorption test. This is reduced first with sewage to 800 to 1000 p. p. m. and later with sewage tank effluent to between 100 and 200 p. p. m. before it reaches the sand filters. These filters are less than 3 feet deep and treat an average of 65 gallons per square yard daily. Biological life is maintained on the sand filters; in fact less ponding is experienced than when ordinary tank effluent is treated and the filters have remained clean for two years. The purification thus effected averages for four months 71.6 per cent (reduction of oxygen absorbed).

Advantages of this procedure are: control of the dilution of gas liquor at the sewage works, efficient purification and even desirable dilution of the ordinary sewage tank effluent going to the percolating filters.

In the discussion of this paper Mr. W. H. Duckworth of Salford stated that, if gas liquor did not exceed $1^1/_2$ per cent of the sewage flow, no trouble was experienced on sewage beds. At Oldbury, many years ago excessive amounts of gas liquor were treated by triple filtration at the sewage works. Mr. Ledson pointed out that processes for recovery of sulphate of ammonia by gas works was unprofitable because of the low sale price of the product. He also mentioned the German experiments of recovery of other by-products from gas liquor. At Essen about 70 per cent of the

phenols are extracted by the benzol washing process, the benzol being afterward recovered. This plant is just about paying its way.

Mr. M. Morris of Wigan stated that for every ton of coal carbonized about 20 gallons of liquor were produced and that for each 500 to 600 population one ton of coal was required for gas production. At Wigan the gas liquor was turned into the furnaces and completely and efficiently evaporated.

Mr. Lockett of Manchester remarked that in the sand filter treatment of gas liquor a heavy growth of organisms was encouraged which, although playing a very small part in oxidation of sewage matters, were very useful in treating gas liquor.

Mr. Chorley, in closing, stated that the gas liquor constituted about one per cent of the dry weather flow.

The Admission of Trade Refuse to Sewers

BY J. H. GARNER

Paper presented at Conference of the Association of Managers of Sewage Disposal Works, London, Nov. 19, 1931. Abstract and discussion in *The Surveyor*, **80**, 519–520 (Nov. 27, 1931); **80**, 575–576 (Dec. 11, 1931); and **81**, 81–83 (Jan. 22, 1932)

ABSTRACTED BY J. K. HOSKINS

It is generally realized by those engaged in stream sanitation procedures that industrial waste pollution can be controlled best by discharging such liquids to the public sewers and treating them with the domestic sewage. By this procedure separate, small, inefficiently operated plants are replaced by one purification works under skilled supervision. River Boards have encouraged authorities and industry to adopt this method wherever possible. The Royal Commission on Sewage Disposal have recommended that the local authority (municipality) should make provision for industrial waste as well as for domestic sewage collection including treatment, without charge, provided the manufacturer complied with the regulations respecting the preliminary treatment of the trade waste. Later the Commission conceded that the local authority might charge for the treatment of industrial waste so contributed.

The Second Report of the Joint Advisory Committee on River Pollution (1930) considers quite fully the matter of the reception of industrial wastes by the public sewer system. The object of the author's paper is to bring about a discussion of the following recommendations of this Joint Advisory Committee.

"We recommend that Section 7 of the Rivers Pollution Prevention Act, 1876, be repealed and the general law amended, on the lines of the clauses which we append, to provide:

(*a*) "That the local sanitary authority should be under a general obligation to take and dispose of the trade effluents of their district and that the trader should have a correlative right to discharge such liquids to the public sewers; and that for this purpose the local authorities should have the same powers and duties for the disposal of these trade effluents as they already have for the disposal of the ordinary sewage under the Public Health Acts.

(*b*) "That the local authorities should be empowered to make general regulations, governing the exercise by the trader of his new right and imposing necessary safeguards and conditions with which he must comply; that the terms of these regulations should be settled by agreement with representatives duly appointed for that purpose by the traders or, in default of such appointment, by the local authority acting alone; that, where agreement proves impossible, questions in dispute should be determined by the Minister of Health; and that either party should be able at any time to call for the modification of the regulations, such modification to be effected in the same way as their initial drafting.

(*c*) "That it should be competent to the local authority, by means of these regulations, to call for necessary preliminary treatment and the removal of specified substances, where practicable, and for the regulation of the rate and volume of discharge; to impose reasonable charges for the facilities afforded; and to provide for the proper measurement of quantities, inspection of effluents and taking of samples.

(*d*) "That the local authority should be enabled to construct or provide, if they so desire, separate sewers or works for the reception and disposal of these wastes or by means of combined schemes to receive and dispose of wastes from two or more trade premises separately from their general sewerage system; that they should have power to combine with the local authority of any other district for the exercise of their functions; and that they should be authorized to execute works on the manufacturer's behalf and at his expense, if such works be rendered necessary for compliance with the regulations, or alternatively to advance to him the cost of the works on terms to be agreed between them.

(*e*) "That the local authority should be empowered to remove and dispose of sludge and similar matter from the trader's premises at his expense.

(*f*) "That the local authority be given a right of entry to and inspection of trade premises at reasonable hours, through their authorized agents.

(*g*) "That the local authority be expressly enabled to enter into special agreements with individual traders as to the terms and conditions on which effluents should be accepted; that existing written agreements, for valuable consideration, should be safeguarded; and that other existing connections with the sewers should be brought into line with the new general system.

(*h*) "That certain substances should still be definitely excluded from the sewers.

(*i*) "That nothing in the new code should be deemed to affect existing riparian rights in the volume of water or to relieve the trader of any obligation which he would otherwise have in that connection.

(*j*) "That the Minister of Health should have power to extend the various periods prescribed in these recommendations, or to suspend the operation of the system in any area, where he is satisfied on application that such extension or suspension is necessary.

" 'We are convinced that legislation on the lines advocated by us in this Report is not only desirable but urgent. It is possible that our future enquiries may lead us to recommend further revision of the law, but we feel that legislation should not for that reason be deferred and that effect should be given to our present recommendations at the earliest opportunity.

" 'We would again emphasize that these recommendations, as a whole, are based upon precedents which have already received Parliamentary sanction in local legislation and that the code which we advocate represents little more than the extension of a system which has already been well tested in local practice.' "

The lack of uniformity of conditions regarding the present methods of industrial waste disposal makes difficult the control of industrial waste pollution. In some sections there is no restriction imposed upon the manufacturer while in others regulations are enforced requiring various degrees of preliminary treatment and payment of charges for use of the city sewer. In some places industrial wastes are not admitted to the sewers and in such places individual treatment plants are frequently defective in operation. Confusion also results where industries have gained prescriptive right of admission of their waste to the sewers, and where sewers are too small to accommodate increasing volumes of trade refuse. Some localities even offer inducements to industry in the form of favorable facilities for the treatment of their trade effluents. Certain local authorities have secured private acts of Parliament that enable them to standardize the procedures with industry, based largely on the recommendations of the Royal Commission of Sewage Disposal. However, much depends upon effective coöperation of industry and authorities in carrying out waste treatment agreements. The success of such coöperation has been demonstrated in the West Riding of Yorkshire area where in over 100 cases trade wastes are received into municipal sewers under widely varying financial agreements.

Progress in stream sanitation under such procedure is, however, painfully slow and the need for legislation, as recommended by the Joint Advisory Committee, is urgent. The amalgamation of smaller sewage dis-

posal plants is bound to follow the enactment of such laws, a distinct forward step. Among the disadvantages are, in special cases, the excessive proportion of industrial waste from large industries that might be added to the sewage of small communities, and the infringement of riparian rights where a manufacturer who withdraws water from a stream and after using it directs it to the public sewer instead of returning it for the use of down-stream owners.

In the discussion of the paper Mr. J. H. Edmondson criticized the recommendations as being one-sided in favor of industry, in that local authorities were required to admit and treat trade wastes although there was no obligation for industry to avail itself of these facilities. Again the standards of purification required might be difficult to meet in the case of excessive amounts of certain trade wastes and in such cases special standards within safe limits of stability should be allowed. No alteration of the standard for domestic sewage effluent is made when the sewage and trade waste are treated together.

Mr. W. D. Scouller pointed out that preliminary treatment of trade effluents by the industry might be inefficient in the hands of unqualified men and that at Huddersfield nearly all manufacturers preferred to pay the municipality for complete treatment rather than to install preliminary treatment themselves. Moreover, many chemical wastes alone are not amenable to biological purification but diluted with domestic sewage can be handled satisfactorily. He pointed out that under the recommendation of the Joint Committee for permissible exclusion of certain substances by the Santiary Authority many liquids might be excluded which could be reasonably treated.

Mr. F. R. O'Shaughnessy stated that an additional advantage of treating trade wastes and domestic sewage together was that the protein matters of various kinds were mutually destructive when manipulated properly in a purification plant and that the protein matter of sewage was a real asset in effecting biochemical purification of industrial wastes under aerobic conditions.

D. H. T. Calvert of the Ministry of Health suggested that the discharge of trades wastes into public sewers was a subject for coöperation between local officials and manufacturers even to the point of modifying processes to facilitate treatment. The importance of such coöperative spirit was emphasized by other speakers.

Dr. E. Ardern stated that since in any case legislation was required, this was an opportune time for the creation of catchment area boards with executive powers to deal with all questions of stream pollution in their respective areas. Such boards would be representative of local authorities, industry, agriculture and raparian owners and have power to levy charges on the local authorities. He considered that there were

many instances where it would be advisable to centralize trade waste treatment rather than mix wastes with domestic sewage.

The consensus of all discussion was that some uniformly regulatory procedures for discharge of industrial wastes to sewers is urgently needed.

The Purification of Waste Waters from Beet Sugar Factories—West Riding of Yorkshire Rivers Board

Second Supplementary Report

BY J. H. GARNER AND J. M. WISHART

Report, No. 169 (October, 1931), 29 pp.

ABSTRACTED BY H. GLADYS SWOPE

Introduction.—In a previous report, No. 166, it was recommended that the beet washing water, process water and lime sludge be treated separately.

The Ministry of Agriculture and Fisheries in its publication "Report on the Sugar Beet Industry at Home and Abroad" on pages 196–7 recommends that the wash water with the flume and transport water be kept separate and after settling be recirculated for use. The condenser water could be discharged into the river directly. The process waters should be kept separate, of which the diffusion water could be recirculated in the diffusion battery for flushing purposes only, and the pulp-press water could be mixed with the lime sludge and transported to storage tanks. As the pits are drained and the lime sludge dries, the liquid can be filtered through gravel, treated with ferrous sulphate and lime and the effluent discharged into the river.

Biological treatment as tried at Rothamsted and Colwich was prohibitive due to the cost. The Cantley factory is now experimenting with biological filtration following fermentation.

Poppleton Beet Sugar Factory.—This factory has now been in operation for five seasons. As the Raabe or continuous diffusion process is used no "process water" is produced. The only waste water is that used for transporting beets from the silos to the factory, and from the washing of the beets. The waste lime sludge from the purification of the juice by the carbonation process is pumped to separate lagoons, from which there is no effluent, and from which the air-dried lime is periodically removed.

The treatment given the waste waters in the 1929–30 campaign consisted of grit chambers, with elevators for the removal of readily settleable sand and grit; screening apparatus for the removal of leaves and rootlets; and a large settling pond subdivided by banks into four sections for use in

series. Lime was used as a precipitant. Kiln waste, containing about 65% of lime (CaO) was added to the inlet of the settling pond at the rate of one ton per day for the first fourteen days. At the end of this time the effluent from the final settling pond showed signs of septicity and the addition of lime was discontinued. After a lapse of $2^1/_2$ weeks lime was again added but at the rate of one-half ton per day. No lime was used during the last ten days of the campaign.

Weekly samples were taken of the crude waste and of the final effluent and analyzed, as were also samples of the river water above and below the effluent outfall.

During the 1929–30 campaign, extending over a period of 52 days, 54,048 tons of beets were sliced. The maximum for one day was 1378 tons. The average amount of soil removed in the washing process was 16.42 lb. per hundred weight or 14.66 per cent. The volume of unfiltered river water used was 227,700,000 gallons and 10,464,000 gallons of filtered water. The bulk of the unfiltered water after being used for condensing purposes was recirculated for use in conveying the beets from the silos. The bulk of the floor washing water from the evaporation and centrifuging departments, which often contains an appreciable amount of sugar from the overflowing tanks, was put back into the process.

The grit chamber and screen together removed 3710 tons of sand, soil, beet tailings, etc. The lime filter press cake produced in the first carbonation process was 6000 tons and 250 tons in the second carbonation process or a total of 6250 tons (50% moisture). The average total daily volume of waste water flowing through the settling ponds was 4,209,660 gallons.

For the 1930–31 campaign an additional grit chamber and dredges were added to the treatment plant. Also, the banks of the first settling pond were raised and the tops reinforced with sand bags. The overflow weirs between the ponds were reconstructed in concrete and timber and made wider. The waste waters flowed through the two catch pits in parallel, then through the fine bar screen and through the four settling ponds in series.

Septicity was again noted in the final settling pond by a too constant use of lime. Alumino-ferric was then tried as a precipitant, the results of which will be discussed later.

The final effluent was diluted by overflows of clean water from the factory supply tanks and with condensing water not needed for conveying and washing the beets before discharge to the River Ouse. Such dilution, however, only reduced the polluting constituents 10 per cent.

The 1930–31 campaign extended over a period of 87 days during which time 123,649 tons of beets were sliced. The average amount of dirt, etc., removed in the washing process was 14.73 lb. per hundred weight or 13.15 per cent. The volume of unfiltered river water used was 402,040,000

AVERAGE ANALYSES OF WEEKLY SAMPLES
1929–30 AND 1930–31 CAMPAIGNS
(Results Expressed in Parts per Million)

	Total Solids	Susp. Solids Total	Susp. Solids Fixed	Nitrogen Org.	Nitrogen NH_3	Chlorides (as NaCl)	Alkalinity (as $CaCO_3$)	Acidity (as CO_2)	Dissolved Oxygen Absorbed in 5 Days at 65° F.	Dissolved Oxygen
Conveying Beet Washing Waters:										
1929–30	4368	3884	3142	33.40	4.21	31.5	201.4	nil	183.8	.....
1930–31	3907	3505	2951	29.38	5.37	27.0	208.0	22.2	147.2	.....
Final Effluent:										
1929–30	643	307	233	6.78	5.54	29.6	175.0	nil	124.2	.....
1930–31	638	299	232	7.85	6.67	24.8	204.5	6.2	90.9	.....
River Water above Effluent Outfall:										
1929–30	278	72	59	0.72	0.025	23.8	89.2	..	1.7	11.8 at 5.8° C.
1930–31	266	26	23	0.66	0.025	23.0	119.1	..	1.1	11.6 at 6.2° C.
River Water below Effluent Outfall:										
1929–30	266	55	45	0.66	0.028	23.8	91.3	..	1.3	11.7 at 5.8° C.
1930–31	268	24	21	0.66	0.036	23.2	119.1	..	1.4	11.6 at 6.2° C.

gallons and 13,760,000 gallons of filtered water. The waste waters were more concentrated during this campaign due to a greater tonnage of beets with only a small increase in the volume of water used. The entire volume of waste waters received full treatment through the grit chambers, screen and settling ponds. The grit chambers and screen together removed 7945 tons of material. The total amount of lime filter press-cake (50% moisture) produced in the carbonation processes was 15,789 tons. The average daily volume of waste water flowing through the settling ponds was 4,325,784 gallons.

Average analyses of the waste waters, effluents and river water for both the 1929–30 and 1930–31 campaigns are given in the following table.

Experiments Relating to the Use of Lime and Alumino-Ferric as Precipitants for Beet Sugar Factory Waste Waters.—As the final effluent tended to become septic when lime was used as the precipitating agent comparative tests were made with lime and alumino-ferric.

The mean temperature in the four ponds under actual operating conditions was 80–90° F. For the laboratory studies the temperature was controlled at 80° F. Samples of beet washings to which different amounts of lime and alumino-ferric had been added were put into a series of stoppered bottles and also into wide-mouthed, open bottles. After three days the appearance of the samples was noted and oxygen, absorbed by $N/80$ $KMnO_4$ in 3 minutes, was determined. After nine days the physical appearance was noted and the oxygen absorbed determined.

After three days an excess of lime promoted putrescibility whereas the alumino-ferric did not. All samples in closed bottles were putrescible in nine days. The open bottle with alumino-ferric did not give as high oxygen absorption figures as those treated with lime.

Report of the Sugar Beet Industry at Home and Abroad

BY A. WOOD, J. H. GORVIN AND B. A. FORSTER

Ministry of Agriculture and Fisheries, Economic Series, **27**, H. M. Stationery Office, London, 1931

ABSTRACTED BY P. D. MCNAMEE

The treatment and disposal of by-products of the sugar beet industry is included in Part IV of the report. The results of the research into the use of biological filters undertaken under the direction of the Water Pollution Research Board are mentioned. The recommendations of the factory technical experts made at the end of 1929 include the recirculation, after sedimentation, of washing and fluming water, direct discharge of con-

denser water, recirculation of diffusion water for flushing purposes only and storage of pulp press water with lime sludge, followed by filtration of the liquid on gravel filters and treatment with ferrous sulphate and lime before discharge into the river.

Technical and Economic Considerations of Decantation and Filtration

BY B. WADSTED

Chem.-Ztg., **55**, 454 (1931)

ABSTRACTED BY P. D. MCNAMEE

The removal of solid matter from valuable liquors can be effected by the filter press method, the Dorr decantation method and the dipping or rotary suction filter methods. The filter press method requires much water and is useful only when the solution contains small amounts of suspended matter. When the solution contains a large amount of suspended matter and sedimentation is rapid, the Dorr counter-current decantation system is most economical. This process is automatic and requires little supervision. The dipping suction filter consists of a frame covered with filter cloth which can be put under a vacuum. It is dipped first into the suspension itself and then into vessels containing liquids of decreasing concentration. The dipping suction filter is used when sedimentation is slow. Series filtration by rotary suction filters is used to obtain an especially good filtrate.

Grand Rapids Improves Its Sanitation—River Pollution Relieved and Sewer System Expanded

BY MILTON P. ADAMS

Civil Engineering (A. S. C. E.), **1**, 1369–1374 (Dec., 1930)

ABSTRACTED BY H. W. STREETER

Problems of flood control are closely related to sewage collection and disposal at Grand Rapids, which is located on the Grand River 40 miles above its mouth at Lake Michigan. The city being situated at the point of maximum variation of river stages in times of flood, a combination of sewerage and flood control works, costing upward of $1,000,000, was built prior to completion of the treatment plant in October, 1930. At this time the population of the city was 168,592 and its area 23 sq. miles.

During 1919–20 an experimental sewage treatment plant was operated

and a gauging and sampling survey of the city sewage was made. The principal difficulty disclosed by the experiments centered around the waste of a strawboard factory, amounting to about $^1/_5$ of the total volume of sewage to be treated. Separate treatment of this waste by vacuum filters has been arranged.

An important step in the program has been construction of a comprehensive system of relief and storm-water sewers, necessitated by flooding of basements during storms of even low intensity. A large portion of these sewers ranged in size from $6^1/_2$ to $11^1/_2$ ft. diameter. For this work the monolithic type of construction, using steel arch forms, was adopted. Most of the work was in open cut, with all types of underground conditions.

Up to March, 1928, the total cost of the sewer project had been $3,350,000, of which 3.7 per cent represented engineering and inspection. In October, 1931, when the treatment plant had been completed, the total cost of the work, including the treatment plant, was $4,600,000.

Grand Rapids Improves Its Sanitation—Primary Sewage Treatment Works Completed

BY C. R. VELZY

Civil Engineering (A. S. C. E.), **1**, 1374–1377 (Dec., 1931)

ABSTRACTED BY H. W. STREETER

The Grand Rapids sewage treatment works, placed in operation in November, 1931, was designed for a population of 250,000, with provision for an ultimate extension so as to take care of 500,000 people. With a tributary population of 157,000 at the time of design, the dry-weather flow of sewage was estimated as 25 m. g. d., or 159 gals. per capita.

From many analyses of the sewage made prior to designing the works, it was estimated that with a population of 250,000 and a daily flow of 33.5 m. g. d., the sewage would contain 185 p. p. m. of suspended matter and would have a 20-day B. O. D. of 225 p. p. m.

After considering four general methods of treatment, it was concluded that sedimentation, with separate digestion tanks and aeration, was the most suitable process. The total annual cost for aeration and sedimentation was only slightly higher than for sprinkling filters and the first cost was lower—an important consideration in the case at hand.

As designed, the works consisted of coarse screens, grit chambers, primary settling tanks, aeration tanks, final settling tanks, sludge digestion tanks, a pumping station, sludge storage tanks, sludge beds and a main building, housing blowers, workshop, garage, laboratory and offices. Also included were 4000 ft. of inlet sewer, a dike surrounding the area (56 acres) for flood

protection, a bridge over the relocated creek and, ultimately, a proposed boulevard along the Grand River bank and an outfall to this river. In arranging the works an effort was made to keep the line of flow straight and short and in a down-stream direction with reference to the river.

Interesting features of the design are mechanical means provided for cleaning the grit chambers, removing sludge from the settling tanks, skimming grease and scum from the sewage surface and for stirring sludge in the digestion tanks. Provision is made for collecting the gas from the sludge digestion and utilizing it for heating the digestion tanks up to 90° F., by means of hot water circulating coils. Storage tanks having a capacity of 1.375 cu. ft. per capita are provided for winter sludge.

Although aeration and final settling were not provided for in 1930, the design included both features, the aeration tanks being given a retention period of 4.5 hours and to be supplied with air at the rate of 0.8 to 1.0 cu. ft. per gal. The final tanks will provide a retention period of 2.7 hours and a settling rate of 850 gals. per sq. ft. per day for the average flow.

Odor Nuisance Surveys

BY H. L. THACKWELL

Civil Engineering (A. S. C. E.), **2**, 80–81 (Feb., 1932)

ABSTRACTED BY H. W. STREETER

In odor control studies, the first step is to make a fact-finding survey, to locate all forms of possible nuisances, such as privies, live stock pens, sewer gas flues, septic tanks and open drains receiving waste water in the neighborhood of the complaining area. Besides the nuisances, all houses connected to sewers and water supply wells and other relevant features should be shown. These data should be plotted on a study map. Circles should be drawn at 500-ft. intervals from the disposal plant as a center, showing at a glance the air-line distance from the plant to any house or object.

Odor studies may be made by observing the path of a smoke screen or smudge and plotting its course, with notations as to time, humidity, atmospheric pressure, dispersibility and height of travel of the smoke flag, wind velocity and temperature. Odorous plant gases will tend to follow the general direction of a smoke cloud originating near the plant.

A corresponding map should be used for each day's observation, on which is plotted the course of smoke flags or odors. Notes should be recorded as to the location of odors observed at various points. The study maps should be marked into 12 sectors, each 30°, having their vertex at the disposal plant. Observations should include the percentage of

time that prevailing winds are observed in each sector; also the percentage of time that odors are noted in conjunction with prevailing winds and at various distances out from the center of origin of odors. It is advisable to use a color scheme for quick perception of plotted data, such as red for the smoke cloud, green for areas of observed odors and black for critical observation points. The observer should check up all rumors of nuisances. A single month's record, especially during the hottest month, usually reveals the true situation.

From records made of odors at Jacksonville, Texas, during August, 1930, only one observation showed odors over 1000 ft. from the plant (during a good northeast wind). On another occasion when plant odors were noted in line with the smoke flag, there was a very slight air movement, not exceeding 3 miles per hour.

Regarding the movement of air currents from the plant, the following conclusions were drawn: Lulls aid in lifting gases into the moving, upper air currents. If the movement is slight, the gases will fall again when cooled and will travel or diffuse along the ground. Winds dilute the gases in proportion to their velocity. Beyond a certain concentration, the intensity of an odor is not in direct ratio to its dilution. Odors are not perceptible below a critical density. Dilution will vary approximately as the square of the distance from the origin.

Many reports of odors from the disposal plant were received when the tell-tale smoke flag indicated that the wind was blowing in a different direction. In such cases, examination of premises always disclosed some bad local condition, such as pig pens, chicken yards, privies and cesspools. There is a certain psychological objection to anything pertaining to sewers that causes people to blame disposal plants for all objectionable odors.

As a result of the survey at Jacksonville, and the conditions surrounding the sewage plant, the city inaugurated a clean-up campaign. Since strict local sanitary measures have been used, no further complaints of odors have been made.

Providence Sewage Disposal Plant

Municipal Sanitation, **3**, 28 (Jan., 1932)

ABSTRACTED BY E. HURWITZ

The Providence sewage disposal plant has a capacity of 50 m. g. d. and treats all normal domestic sewage together with a large amount of waste from textile and other industries and some storm water.

Sewage is carried to the plant by an 88-inch circular sewer and passes first through two mechanically cleaned automatically controlled Dorr bar screens with three-quarter inch openings. It then flows through two

detritors equipped with grit cleaning compartments. The capacity of the detritors is such that they are able to remove other rapidly settling materials, such as corn and mash, in addition to grit. The sewage is then presettled in two clarifiers and is finally aerated with 25 per cent of return sludge for four hours.

The screenings are collected and are burned in the municipal incinerator or barged out to sea along with the grit and sludge press cake from the filter presses.

The final effluent will be chlorinated and discharged into the tide-water.

Chlorine in Sewage Treatment

BY R. F. GOUDEY

Municipal Sanitation, **3**, 10–14 (Jan., 1932)

ABSTRACTED BY E. HURWITZ

Reduction in the price of chlorine to a point where it is economically feasible, and stimulation of interest in its application, have found for chlorine a definite place in sewage treatment. For disinfection it is the most reliable and most practical agent known. Reductions in bacterial counts of 99 per cent or greater can be obtained when a residual of 0.2 p. p. m. is maintained after 10–15 minutes. The efficiency of chlorine as a disinfectant is dependent on the dosage and period of contact between the chlorine and the sewage. These factors will vary with the type of sewage and the flow.

Control of odors with chlorine is secured by chlorination of the entire body of sewage to prevent the formation of hydrogen sulphide as well as to neutralize it, and by chlorinating the atmosphere in pump sumps to destroy gases which are likely to escape into the air. Incidental with checking odors, the chlorine applied to sewage prevents the disintegration of the concrete pipe and other concrete structures by hydrogen sulphide. Prechlorination of sewage in Imhoff tank plants and chlorination in long outfall sewers has been very effective in keeping down odors.

Chlorine has also found application in the elimination of filter clogging and in combating filter flies. It has been effective to a small degree in reducing the B. O. D. in sewage effluents and in checking foaming in Imhoff tanks. It is also used in the manufacture of ferric chloride coagulant, used in dewatering activated sludge either on sand beds or with vacuum filters.

The author enumerates specific plants where chlorine has been used for one or more purposes in sewage treatment and relates the results obtained at each plant.

Chlorination of Sewage

BY C. K. CALVERT

Ind. Eng. Chem., **24**, 92–94 (1932)

ABSTRACTED BY P. D. MCNAMEE

During the summer of 1930, clarified Indianapolis sewage was chlorinated with the hope of improving river conditions. The chlorine was applied to the sewage as chlorine solution, ice and gas by means of improved delivery devices, illustrations of which are included in the text.

It appears that large doses of chlorine may not reduce B. O. D. in the same proportion as small doses and that the chlorine may combine with substances in the sewage to render it inactive to starch-iodide tests and yet reduce the B. O. D. inappreciably. Laboratory determinations were made three times daily (during the peak load period) of the B. O. D. and chlorine demand, before and after chlorination. The chlorine demand is reduced from seven to ten times as much as the B. O. D. Chlorination reduced the 5-day B. O. D. less than ten per cent. The effluent of the activated-sludge plant was chlorinated as well as the clarified sewage in order that free chlorine would be maintained in the river itself. The minimum dissolved oxygen within the first six miles of river flow was taken as a measure of the river condition. There was no material change in the oxygen content of the river on account of chlorination of sewage and plant effluent. No improvement in operation was noted following chlorination of the influent of the activated-sludge plant.

Indole and Skatole in Sewage

BY WILLEM RUDOLFS AND NOEL S. CHAMBERLIN

Ind. Eng. Chem., **24**, 111 (1932)

ABSTRACTED BY P. D. MCNAMEE

Indole and skatole are nitrogenous degradation products. When diffused into air, extremely small quantities can produce penetrating odors. These chemical compounds were determined in three types of sewage disposal plants. The sewage plants selected were: Plainfield, N. J., consisting essentially of a fine screen, settling tanks, sprinkling filters and digesters; Red Bank, N. J., with clarifier unit and digesters; and Madison-Chatham, N. J., with sedimentation and activated sludge. The following table shows the results of the experiments:

Plant	Parts per Billion Indole	Skatole
Plainfield, N. J.:		
Screened sewage	0.25	0.38
Settling tank effluent	0.12	0.25
Sprinkling filter effluent	Trace	Trace
Red Bank, N. J.:		
Raw sewage	0.25	0.19
Clarifier effluent	0.12	0.12
Madison-Chatham, N. J.:		
Raw sewage	0.25	0.19
Settling tank effluent	0.12	0.12
Aeration tank effluent	Trace	Trace

Oxidation devices appear to be very effective in removing these substances, and it is possible that odors produced by these substances can be controlled by alkalies or chlorine.

Twenty-Four Hours from Sewage to Fertilizer

BY CHARLES N. TUNNEL

The American City, **46**, 70 (Jan., 1932)

ABSTRACTED BY E. HURWITZ

Houston at the present time is pressing and drying 15 tons (dry basis) of sludge per day. Chlorinated copperas, used as the coagulant, is manufactured on the ground from chlorine, bought in ton containers, and copperas. The conditioning equipment has a variable control so that the amount of coagulant may be varied as the condition of the sludge demands. An over-and-under baffle tank distributes the chlorinated copperas through the sludge. The pH is measured electrically before the sludge is routed to the filters.

The filtering equipment consists of a battery of four Oliver United disk filters having a total filtering area of 3200 square feet. The press cake is carried by screw conveyors to rotary driers. These are the direct—indirect heat type and are oil-fired.

The dry sludge is carried by belt conveyor fitted with magnetic separator to remove scrap iron, nails, etc., to a Hummer screen. The tailings are routed back to the feed end of the conveyor and mixed with the wet sludge cake. The material passing the roughing screen is conveyed to two screens arranged in tandem, one of which removes the dust, the other the finished product. The tailings are ground and rescreened. The finished product, Hu—Actinite, is weighed and stored into bins from which it is loaded into box cars for shipment.

It is estimated that the sale of the fertilizer pays for pressing and drying the sludge.

The Sewerage System at Singapore

BY WALTER BUCHLER

Municipal Sanitation, **3**, 15–17 (Jan., 1932)

ABSTRACTED BY E. HURWITZ

The sewerage system at Singapore consists at the present time of about 46 miles of sewers ranging from six inches to forty-two inches in diameter. The sewage collected in this system and an enormous quantity of night soil, which is collected in special pails and delivered by lorry to two pumping stations, is treated at the disposal works. It passes first through a screen to remove rags, etc., and then through detritus tanks. From the detritus tanks the sewage is treated in Imhoff tanks of which there are thirty-two. After two to three hours' detention period the Imhoff effluent is discharged onto filter beds served by revolving arms. These beds are 100 feet in diameter and number fifty-five. The filter effluent is settled in humus tanks. The sludge from the Imhoff and humus tanks is dried on beds. When sufficiently dry the Imhoff sludge is buried because of the presence of hookworm. The sludge from the humus tanks contains no hookworm and can be used as fertilizer. Experiment is being carried on with partial oxidation of Imhoff effluent prior to discharge onto filter beds.

Starting a New Sewage Disposal Plant

BY STIRLING L. WILLIAMSON

The American City, **46**, 71 (Feb., 1932), also *Municipal Sanitation*, **3**, 29 (Jan., 1932)

ABSTRACTED BY E. HURWITZ

The Moores Creek plant at Charlottesville, Va., was completed in February, 1931, but was not put into operation until April. The plant serves a population of 8000 and treats the sewage from the southern section of the city. It provides only partial treatment, being equipped with bar screens and Imhoff tanks. Chlorination for odor control and sterilization of the Imhoff effluent are provided. Sludge is dried in glass-covered beds. Screenings are buried.

To start the plant 1300 gallons of ripe sludge was secured from Harrisonburg and used as seeding material in one Imhoff unit. Lime was added daily. In spite of this the pH dropped below 6.0 in about two weeks and continued in an acid condition for eight weeks, after which the pH rose gradually to 7.0. Simultaneous with the rise in pH, gas production increased, digestion proceeded more rapidly and foaming practically ceased.

The second Imhoff unit was started in June. The tank was seeded with a mixture of sludge from the first unit and Harrisonburg sludge. This time the sewage was prechlorinated. The effect of this treatment seemed to favor more rapid digestion. The trend of the second tank was similar to that of the first but less lime was required and the initial acid condition lasted only about five weeks as compared with eight in the first unit.

Enlarged Sewage Treatment Plant for Small City Stresses Odor Control

The American City, **46**, 66 (Feb., 1932)

ABSTRACTED BY E. HURWITZ

The Newton, N. J., sewage treatment plant was redesigned with particular attention toward the elimination of odors in all parts of the plant. The raw sewage is chlorinated with dosages of 6 to 7 p. p. m. at the grit and screen chamber. It then passes through settling tanks provided with covers and mechanical clarification to prevent septic action. The sewage is next treated on glass-covered trickling filters. Because of its fresh condition on entering the plant, residual chlorine can be detected at the trickling filter nozzles. To insure a chlorine residual throughout the plant a second dose of chlorine is applied ahead of the secondary settling tanks. The effluent from these tanks is well clarified and drains through the sand beds, onto which it is discharged, very rapidly.

The sludge is digested in separate tanks, also covered, and dried on glass-covered sand beds. Drainage from the sludge bed is chlorinated with hypochlorite of lime before discharge. Screenings are buried.

It is planned to collect and burn the gas produced in the digestion tanks to eliminate odors from this source. The heat generated will be used in the plant.

Improving Appearance of Jersey City Sewage Disposal Grounds

BY W. C. MALLALIEU

Public Works, **63**, 24 (Jan., 1932)

ABSTRACTED BY C. T. WRIGHT

Jersey City, N. J., has constructed and operates a sewage disposal plant in the Rockaway River valley on the outskirts of Boonton, N. J. The plant is under the direction of the Commissioner of the Department of Streets

and Public Improvements, being more particularly a part of the water bureau. Its primary function is the protection of the city's water supply, through the diversion of the sewage originating in the water-shed, to a site immediately below the reservoir dam.

The plant is spread over an area of about 22 acres, room being left adjacent to each unit to permit enlarging or duplicating it when the necessity arises. The treatment of the sewage consists of plain sedimentation and separate sludge digestion, with both series of tanks roofed, covered with earth, and having terraced sides; glass-covered sludge drying beds, slow sand filters and final sterilization with detention tanks.

The lack of crowding on the site of the works has provided an excellent opportunity to beautify the grounds. After three years of operation without nuisance and through the gradual improvement of the grounds the plant is looked upon as a park and a desirable place to visit.

The program has entailed an expenditure of $900 over a period of five years and has made possible the filling in of two bog areas, space being provided, before filling, for lily pools. The filled area was covered with a heavy coating of sludge, thus providing an excellent base for the lawns. In the foreground, sighted from the settling tanks, a bed of white nicotiana about 110 by 135 ft. in extent is provided. This plant blooms at night and gives off a spicy attractive fragrance, noticeable for a considerable distance. The attractive drives winding throughout the site are lined with ornamental lighting posts. Along some of the sections of the drives hedges are provided in place of fences. A nursery has also been provided for the supply of evergreens to be used in the reforestation of the marginal area of the reservoir.

Various views of the plant site accompany the article, illustrating the marked improvement which landscaping has made in the appearance of the grounds.

Financing Sewage Disposal Plants in Ohio

Public Works, **63**, 63 (Jan., 1932)

ABSTRACTED BY C. T. WRIGHT

Twenty-two Ohio municipalities last November voted on bond issues for water supply, sewerage and sewage disposal projects, eleven being for water supplies and twelve for sewerage and sewage disposal (one of these for both). Of these, only three municipalities voted for water projects, only one for sewage treatment and none voted for bonds for sewers. The law requires a 60 per cent majority to authorize a bond issue.

Where the improvements are badly needed, the Ohio State Board of Health recommends the following method of financing. In 1923 the general

assembly enacted a "Sewer Rental Law" which permitted Ohio municipalities to place the sewerage system on almost the same basis as the water system, namely, as a utility. Municipalities are thus permitted to collect charges for sewerage and sewage disposal service on a schedule of rates which the municipality may determine to its own satisfaction. The revenue thus derived may be used for operation and maintenance of the sewerage and sewage disposal devices, and any surplus may be applied to the sinking fund charges on bonds, or for direct expenditure toward sewage disposal improvements.

The first municipality to take advantage of this method of financing was the village of Oxford, which began to charge for sewer service in 1925. The largest city to adopt this method of financing is the city of Dayton, Ohio. Each Dayton householder using the sewer system pays approximately $4.00 per annum. About twenty Ohio municipalities are paying for their sewage disposal service under provisions of the sewer rental law.

Water Supply, Sewage Treatment and Refuse Disposal in 1931

BY H. BURDETT CLEVELAND

Public Works, **63**, 26 (Jan., 1932)

ABSTRACTED BY C. T. WRIGHT

Two notable instances of official action to secure greater progress in the proper treatment of sewage before its discharge into waterways and in the prevention of oil waste discharge were reported during 1931.

A committee of seven engineers, representing four of the major national engineering societies, with Robert Spurr Weston as chairman, was appointed early in the year by the American Engineering Council to aid in framing laws prohibiting "the further unnecessary and wanton pollution of all waters under the federal and State governments."

For the purpose of recommending a treaty between New York, New Jersey and Connecticut, the legislatures of these states during 1931 sessions authorized the appointment of a commission in each state to confer with the other commissions and agree upon a treaty between the three states and the Federal government which shall cover all matters relating to the pollution of natural waterways between the states.

Organization of joint sewer districts and metropolitan boards, to make possible the economical and effective collection and treatment of sewage by arranging that sewer system planning shall conform to natural drainage areas, has proceeded during the year.

In sewage treatment practice, attention has been given to the possibilities of multiple stage digestion of sludge, to wider application of prechlorination for odor control and reduction of B. O. D. as well as for disinfection, and to utilization of digestion tank gas for power purposes.

Report of the Hackensack Valley Sewerage Commission, 1931

ABSTRACTED BY S. I. ZACK

General.—The Hackensack Valley Sewerage Commission was created by enactment of legislation by the State of New Jersey in 1930 for the purpose of relieving and preventing the pollution of the Hackensack River and its tributaries, and to determine approximately the cost of construction and method of financing of a trunk sewer and disposal system.

The commission engaged the services of S. Wood McClane, George W. Fuller, engineers, and Richard C. Smith, chemist and bacteriologist, to prepare detailed studies and estimates, and of a real estate appraisor, actuary and legal advisor for their respective duties.

Description of Hackensack Valley.—The Hackensack Valley Sewerage District as defined by law includes the portions of Bergen and Hudson counties within the natural drainage areas of the Hackensack River and its tributaries lying between Newark Bay and the boundary line between the states of New York and New Jersey. This area covers 146 square miles and has a population of 456,000 according to the 1930 census. In addition, this river has a drainage area of 62 square miles and a population of 24,000 tributary in New York State.

Although the west side of Bayonne is not mentioned in the act creating the district, this area drains into Newark Bay, and the pollution is carried upstream into the Hackensack River. This area covers 1.2 square miles and includes a population of 23,600.

The upper portion of the river is non-tidal and used as a source of water supply for some of the principal communities of Bergen and Hudson counties. The lower portion is tidal, covers an area of 93.0 square miles, of which 35.1 square miles are swampy and water surface, and had a population of 423,000 in 1930 exclusive of the west side of Bayonne.

There are about 40 municipal sewerage treatment plants located north of North Bergen and about a dozen private plants treating industrial wastes from paper mills, chemical works of various kinds and gas and coke works. These have not been wholly adequate in capacity and degree of treatment. Sewage south of North Bergen is discharged without treatment into the Hackensack River and adjacent parts of Newark Bay.

Present Pollution of Hackensack River.—Considering the purification facilities of the Hackensack Water Company, the contamination of the upper portion of the river, used for potable water supply, has not reached a danger point. Rapid growth of Bergen County is expected during the next few years due to the recent opening of the Washington Bridge and therefore pollution should not be allowed to increase materially.

Unsanitary conditions due to pollution exist in the lower portion of the river, rendering the waters unfit for recreational purposes. Sewage solids have been deposited and accumulated into foul and putrefying sludge banks.

Dissolved oxygen under summer conditions is either completely, or very nearly, depleted.

Proposed Plan for Interceptions and Treatment Works.—The proposed project is divided into a northerly and southerly system, each consisting of a separate trunk sewer, pumping station and treatment works. In addition there will be a few separate plants to serve areas too remote from the trunk sewers. The northerly system, excepting six combined sewers carrying storm flow, will receive the flow of separate systems of sewers. The southerly system will receive the flow from a system of sewers that is practically entirely on the combined plan, and will require regulations for diverting most of the storm flows to the river.

The activated-sludge process, consisting of preliminary sedimentation, reaeration and final sedimentation tanks, is proposed for treatment of the sewage. The process is estimated to remove 90 per cent of the suspended solids and organic matter and 95 per cent to 98 per cent of the bacteria. Spiral-flow aeration tanks and sedimentation tanks of either the conveyor or revolving type are indicated as being suitable.

Sludge is to be disposed of by means of digestion in separate heated digestion tanks and drying on beds.

Disposal of sludge at sea by use of sludge vessels is mentioned but considered unsuitable due to insufficient draft in the Hackensack River. Manufacture of fertilizer is not advantageous due to unfavorable market conditions.

Other possible methods for treatment of sewage and handling of sludge, now in the process of development at other cities are suggested, such as clarification by vacuum filters with the aid of waste paper, similar to the Laughlin process under construction at Dearborn, Michigan, and filtration of sludge followed by incineration. One of these sewage treatment methods, if fully developed and found satisfactory, may be applicable for the southerly plant, where a lesser degree of treatment may later be found sufficient.

Present estimates for financing the projects are made entirely on use of the activated-sludge process and digestion of sludge.

The treatment of wastes other than from gas works, coke industries and wastes of high germicidal nature, will be assumed by the District. Whether to treat the wastes at the point of origin or to receive them into the trunk sewer without treatment will be determined in each instance.

BASIC DATA FOR TREATMENT PLANTS (1947 CONDITIONS)

	Northerly Plant	Southerly Plant
Tributary Sewer System	Mostly Separate	Combined
Tributary Population	391,600	284,750
Sewage Flow, G. C. D.	115	120
Prelim. Sedimentation, Hours	1.0	1.0
Aeration Period, Hours	5.6	5.6
Sewage Air, Cu. Ft. per Gal.	1.0	1.0
Reaeration for 25 % Sludge, Hours	4.0	4.0
Final Tanks, Hours Detention	3.0	3.0
Sludge Digestion Capacity, Cu. Ft. per Cap.	3.0	4.0
Sludge Storage Tanks, Cu. Ft. per Cap.	2.1	2.8
Sludge Drying Beds, Sq. Ft. per Cap.	0.6	0.8

Construction and Financing.—The engineers recommend that the construction of the northerly and southerly projects be completed by 1937. The treatment works should be built to meet the needs of 1947 and then expanded, but the trunk sewers must be built in the initial stage to meet the requirements of 1960.

The following table gives a summary of estimated costs and needs for 1947 and 1960 conditions:

	1947	1960
Connected Population	676,350	899,700
Sewage Flow, M. G. D.	82.4	113.2
Miles of Sewer	60	84
Cost of Trunk Sewer per M. G. D.	$ 89,000.00	$ 78,000.00
per Capita	10.90	9.80
Cost of Treatment Plant and Pumping Station per M. G. D.	116,000.00	110,000.00
per Capita	14.10	13.90
Cost of Operation per M. G. D.	24.40	22.60
Cost of Operation per Capita	1.06	1.02

Financing is to be based on a total estimated cost of $20,000,000 for construction and $650,000 annually for maintenance operation and repairs to meet the needs for 1937 and 1947. Additional $4,400,000 will be required for construction and an increase of annual costs to $800,000 to meet the needs of 1960. These estimates include Bayonne and remote plants. If East Bayonne should fail to be included in the District the costs would be somewhat less.

The project is to be financed by means of temporary construction bonds

during the construction period, to be retired by serial bonds issued by each city in the proportions of approximately 60 per cent by Bergen and 40 per cent by Hudson County. The counties are to be reimbursed by the municipalities on the basis of a uniform charge per million gallons delivered to the trunk sewers.

The enactment of legislation is now pending for means of financing and the appointment of a commission composed of members from Bergen and Hudson Counties, with powers to carry out the project and to deal with the various municipalities and private sewer companies.

If the legislation is enacted early in 1932, construction will be started in 1933 and that part to meet the needs of 1947 should be ready for operation by the middle of 1937.

Influence of Diluting Water on the Biochemical Oxygen Demand

BY E. F. ELDRIDGE AND W. L. MALLMAN

Michigan Eng. Expt. Station, *Bull.*, **39**, 3 (July, 1931)

ABSTRACTED BY H. W. STREETER

With a view to obtaining a standardized diluting water for all tests, Mohlman and Theriault have recommended distilled water containing bicarbonate and sodium dihydrogen phosphate, respectively. Noting that the college tap water gave higher B. O. D. results than the bicarbonate water, the authors undertook, adopting the former as a criterion, to compare the results obtained from parallel tests of tap, distilled, carbonate, bicarbonate and phosphate waters, using effluent from the city Imhoff tanks as the seeding medium. The studies were in the two series: (1) the influence of pH on the B. O. D. and bacterial count, and (2) the influence of the mineral constituents of the diluting water on the B. O. D. and bacterial count under constant pH conditions.

The general procedure followed for each type of water studied was: (*a*) seeding with 1 cc. of sewage in a 5-gal. bottle, aerating contents 5 hours and storing for 2 weeks; (*b*) preparation of 2 and 5 per cent dilutions of Imhoff effluent in the stored dilution water, siphoning the mixtures into 250-cc. bottles fitted with water seals; (*c*) incubation of 9 samples of each dilution and of each diluting water at 20° C. for 1, 2, 3, 4, 7, 10, 16, 20 and 26 days, respectively, determining the pH of two additional samples at the start, middle and end of the total period; (*d*) determination of the 48-hour bacterial count at 20° C. on each sample at the time of each B. O. D. test.

In the first series, the five diluting waters with different pH values were used. Trouble was experienced with D. O. tests in the phosphate water,

though fairly good results were obtained if the titration of liberated iodine was made immediately after the addition of acid. The results, given in tables and charts, indicated: (1) a lag in oxidation attributed to the effect of pH on bacterial activity; (2) a smoother curve for the tap water than for the other waters; also higher and more rapid development of B. O. D. and bacterial count; (3) a fair agreement between the trends of the corresponding B. O. D. and bacterial curves; (4) very little change in pH due to products of oxidation; (5) that the type of diluting water greatly influences the B. O. D. results, owing in part to the effect of initial pH on bacterial growth and activity. The data also indicated that although a favorable pH was 7.0 to 7.6, pH value was not necessarily the limiting factor in B. O. D.

In the authors' opinion, if the tap water be considered as a standard, none of the other waters tested would be satisfactory for dilution purposes except with a long incubation period, owing to the high deviations in results obtained with these other waters from those shown by the tap water. These variations are given as 36 per cent at 4 days' incubation and as ranging from 26 to 54 per cent at 10 days.

In the second series, comparative tests were made with the same tap water used in the first series and a synthetic water containing mineral salts in quantities approximating the average for 33 river waters of Michigan. The pH of both waters was the same, 7.28. From tabulated results it is shown that the B. O. D.'s and bacterial counts obtained after various incubation periods were very similar for the two waters. Judging from these results, it is the authors' expressed opinion that a synthetic water such as used in the second series made by dissolving 170 p. p. m. $CaCl_2.2H_2O$, 120 p. p. m. $MgSO_4.7H_2O$ and 230 p. p. m. $NaHCO_3$ in distilled water, would give more nearly the desired results than either bicarbonate or phosphate water. They view the B. O. D. test as a quantitative measure of organic matter, rather than an attempt to simulate stream conditions.

Report of a Sanitary Survey of Brandywine Creek for the Wilmington Water Department, Wilmington, Delaware

BY WILLEM RUDOLFS

197 pp. (1930)

ABSTRACTED BY H. GLADYS SWOPE

The survey was made over the period extending from February 1 through September 30, 1930.

The Brandywine watershed is approximately 325 square miles in area

above the Wilmington water intake. The main tributaries to Brandywine Creek are the West Branch, East Branch, Taylor Run and Buck Run. Only about 5.5 per cent of the total drainage area lies in Delaware, the remainder lying in Pennsylvania.

The results obtained during this survey are particularly significant in that it was the driest season experienced in 37 years, precipitation being 66 per cent of the 37-year average as recorded by the U. S. Government rainfall reports.

The average discharge from February through June, 1930, was 410 c. f. s. and from June to October, 131 c. f. s. These flows are 55 per cent of the average for five years.

Samples were taken at thirteen regular sampling stations located from immediately above the main source of pollution to the Wilmington Water Department intake. The stations were from 1 to 10 miles apart and four were situated in Delaware.

Chemical, bacteriological and biological determinations were made on the samples. During the first period of the survey, samples were collected every hour during the 24-hour period at strategic points to determine as closely as possible when the average conditions existed during the day. Samples were thereafter collected, for the first two months, six times per week and later on every other day.

With the exception of the sample taken at Station 10, all of the samples were taken at mid-depth. At Station 10 the sample was collected a few inches below the water surface.

The industrial wastes entering Brandywine Creek cause the greatest pollution. Of the five industries located below the state line two, the Augustine paper mills and Bancroft mills, discharge their wastes and sewage below the Wilmington water intake. The sewage from the DuPont experimental station receives partial treatment and is chlorinated before discharge into the creek. The chemicals from the plant vary from day to day—some cause odors or tastes and others stimulate growth in the creek and reservoirs, while others interfere with the water plant control. The Rockland paper mills treat their wastes with lime, discharging only the effluent. During 1930 the creek received wastes from 11 larger industries in Pennsylvania, 7 of which were paper mills, 2 steel works and 2 textile mills.

The report contains 57 tables which give detailed analyses, stream flows and pollution loads. Table 12 (p. 70) summarizes the results by seasons and is reproduced herewith. Spring, refers to the period between February and June; summer, between June and September; and the yearly average is the average of these eight months.

The presence and effect of algae on the treatment of the water was studied during the week of July 14, 1930, when a very abundant growth of algae

SEASONAL AVERAGES OF RESULTS

Station	Temperature, ° C.			Dissolved Oxygen Per Cent Saturation,			5-Day B. O. D.			*B. Coli* per Cc.		
	Spring	Summer	Year	Spring	Summer	Year	Spring	Summer	Year	Spring	Summer	Year
1	11.4	25.2	18.3	87.7	87.1	87.5	3.4	4.4	3.9	94.7	10.4	59.0
2	11.4	24.4	18.0	88.2	90.0	89.1	3.1	4.1	3.6	140.2	15.1	78.0
3	11.5	24.4	18.0	87.7	88.8	88.2	2.7	4.3	3.5	240.6	7.8	124.0
4	11.5	24.7	18.1	83.7	80.1	81.9	2.5	4.4	3.5	170.0	12.0	91.0
5	10.1	24.5	18.0	85.0	82.5	83.7	3.2	3.7	3.5	390.0	4.2	197.0
6	10.6	22.7	16.6	82.8	84.7	83.7	3.0	4.0	3.5	168.0	29.5	99.0
11	11.6	23.4	17.5	84.5	89.0	89.0	3.3	4.1	3.7	205.0	60.7	133.0
12	15.9	30.1	23.0	68.5	76.7	72.6	6.3	13.0	9.7	841.0	220.0	531.0
13	11.8	23.7	15.9	90.0	88.5	89.1	2.1	2.8	2.5	3.5	10.2	7.0
7	9.0	22.0	15.5	83.0	69.2	76.1	4.6	4.2	4.4	637.0	114.0	376.0
9	10.2	22.7	16.4	82.8	33.5	58.1	6.6	15.1	10.9	4,361	29,050	16,704
10	10.0	21.1	11.7	99.3	92.0	95.7	3.3	3.4	2.4	52	242.0	147.0
8	9.5	..	..	80.4	..	..	15.8	..	..	4,976	....	....

occurred in the creek. The algae increased the dissolved oxygen in the stream, but its effect at the filtration plant was detrimental. It was necessary to treble and quadruple the alum dosage at the rapid sand plant before efficient coagulation was obtained. Both the slow and rapid sand filters had to be washed more frequently, the latter every 4 to 8 hours instead of 24 hours. The *Selenastrum* organism was only partially retained on the rapid sand filters. The sedimentation of the algae, which subsequently died, produced a flat sweet taste in the water. The microbial decomposition of the algae reduced the dissolved oxygen and increased the free carbon dioxide to the extent that the iron and manganese oxides went into solution.

An interesting observation made at this time showed that the manganese content varied inversely as the dissolved oxygen.

The conclusion reached by the author was that: "The sanitary survey of Brandywine Creek conducted during the summer of 1930. . . indicates that the East Branch and the West Branch of Brandywine Creek are heavily polluted; that ordinarily the waters of Brandywine Creek as entering the state of Delaware from Pennsylvania are in fair sanitary condition, although occasionally the water of the stream is decidedly unsatisfactory for public water supply purpose even at Wilmington, Delaware; and that the principal cause of the pollution and those most capable of abatement are untreated sewage from Coatesville and South Coatesville and the waste waters from certain paper mills to tributaries of Brandywine Creek."

Spiral Sedimentation Plant for Sewage Treatment

BY A. HINDERLES

Der Bauing., **11**, 291 (1930); *Wasser u. Abwasser*, **27**, 213 (1930); Abst. No. 1277, *British Summary of Current Literature, Water Pollution Research* (Nov., 1931)

Model plants in which the sedimentation tank is in the form of an open spiral are being tested at Hanover. When water enters an ordinary sedimentation tank, eddies form and hinder sedimentation for some distance from the inlet. When the water takes a curved course, secondary currents are formed, counter-balancing the inflow current and aiding sedimentation. Solid matter is deposited on the inner side of the curve where the velocity is least. If the channel slopes toward the inner side the material deposited can sink into the digestion tank through slits on the inner side of the channel. Experimental models are of sheet metal with a maximum width of 1 meter, with arrangements for flow in either direction. Results obtained from these models have been satisfactory.

Seventeenth Annual Report of the Sewerage Commission of the City of Milwaukee, Wisconsin, for the Year 1930

Abst. No. 1272, *British Summary of Current Literature, Water Pollution Research* (Nov., 1931)

An account is given of the operation and finances of the plant during 1930. After three years of operation at full capacity, it has been decided to extend it along present lines to deal with extra flow from the Metropolitan Drainage District, the original plant being designed only for the city area. The production of Milorganite has been about 100 tons daily through the year. Trouble has been experienced with heating in the storage of Milorganite. A new type of clarifier has been installed in the sedimentation tanks. The effect of acid wastes from metal works on the sewers and walls of the aeration tanks and steps taken to remove such wastes from the sewage are described. The appended report by the Chief Engineer deals with plant alterations, treatment of odors from sludge drying, plans for plant extension and work carried out in the sewerage system.

The Biological Filtration of Dilute Sucrose Solutions

BY N. W. BARRITT

Biochem. J., **25**, 1419 (1931); Abstr. No. 103, *British Summary of Current Literature, Water Pollution Research* (Jan., 1932)

The fundamentals of biological filtration were studied by passing a liquor containing 0.1 or 0.2 per cent of sucrose through an experimental trickling filter built in sections. Conclusions: The 5-day B. O. D. test is the most satisfactory measure of pollution available, but has the following limitations: (*a*) it is not possible to estimate carbohydrate in terms of oxygen absorption by a biological process, as organic synthesis is an essential part of the process; (*b*) the nature of the inoculum affects the relative amounts of oxidation and synthesis. Organic acids are produced in the decomposition of sugar, but are rapidly destroyed by an efficient filter bed. Lactic and acetic acid are more rapidly oxidized than sucrose; the formation of oxidized nitrogen in the presence of organic matter promotes oxidation of lactic acid and probably other compounds.

The formation of film on the media is essential to purification; the film accounts for 15 per cent of the sucrose supplied. Aeration is the dominant factor in biological filtration. Time of contact and purification are best controlled by adjusting the rate of flow. In a shallow filter a slow rate of flow with high concentration gives higher purification than the reverse.

The growth and efficiency of the film depends on definite nitrogen and phosphorus requirements. Nitrogen fixation occurs in the bed. A low carbon/nitrogen ratio and a high concentration of organic matter favor rapid film development and high purification. With a carbon/nitrogen ratio of 15 or less, a 5-ft. depth filter bed will purify a 0.2 per cent sugar solution at a rate of 100 gals. daily per cu. yd. of filter material (coarse gravel or clinker). High ratios necessitate a much deeper filter, and better results could be secured more easily by adjusting the ratio. Both stages of nitrification occur in the filter and are subject to fluctuations not correlated with the supply of nitrogen in solution.

Determination of Dissolved Carbon in the Analysis of Aqueous Effluents

BY H. BACH AND K. GLAZER

Z. anal. Chem., **85,** 161 (1931); *Chemistry & Industry*, **50,** 1931; *Brit. Chem. Abst. B*, 996; Abstr. No. 218, *British Summary of Current Literature, Water Pollution Research* (Feb., 1932)

The water is boiled with dilute sulphuric acid to expel carbon dioxide, cooled, neutralized with carbonate-free sodium hydroxide and boiled under reflux for 1 hr. with sodium hydroxide, potassium permanganate and H_2PtCl_6 solution. The liquid is then acidified with sulphuric acid and the carbon dioxide is expelled by boiling and collected in sodium hydroxide solution. The latter is treated with barium chloride at 100° C. until no further precipitate is formed; then exactly neutralized (phenolphthalein) with hydrochloric acid. The undissolved barium carbonate is determined volumetrically by solution in excess $N/10$ hydrochloric acid and titration with $N/10$ sodium hydroxide.

Second Report of the Scottish Advisory Committee on Rivers Pollution Prevention—River Esk (Midlothian)

Department of Health for Scotland, H. M. Stationery Office, Edinburgh, 1931; Abstr. No. 1303, *British Summary of Current Literature, Water Pollution Research* (Nov., 1931)

ABSTRACTED BY P. D. MCNAMEE

Pollution of the Esk River by paper mill waste has greatly increased in recent years. The water in the lower stretch of the river is unsuitable for manufacturing use, and when used for condensers causes serious trouble owing to frothing. Treatment of the effluents by sedimentation is inadequate in most cases. One mill produces an effluent which is prac-

tically neutral and which contains only 26 p. p. m. of suspended matter. If such an effluent were produced at all the mills, the offensive condition of the river would be greatly reduced.

Coal-washing plants are another source of pollution. At one of the large collieries no waste water is discharged. The washing water is conveyed first into a silt recovery tank and then into a settling tank. The solid material from both is used for fuel. The supernatant water is recirculated until the suspended matter becomes too great, when it is run off to ash and brick filters. The committee believe that although such a plant may not be practicable at small collieries, a plant embodying the essential principles of sedimentation and filtration would be practicable even there. They lay stress on the removal by filtration of fine coal dust, which is difficult of sedimentation.

Pollution by sewage is rendered less obvious by the industrial pollution; nevertheless it is still appreciable, and crude sewage is frequently discharged. In areas traversed by the grossly polluted Esk, the Midlothian County Council is the sole authority for the administration of the River Pollution Prevention Acts. The committee recommends the expedition of negotiations between the local authorities and the papermakers and colliery owners, the enforcement of the Acts as regards the purification of sewage, and the appointment of full-time river inspector or inspectors.

Bradford's Sewage Disposal Problems

ANON

The Surveyor **81**, 35–36 (Jan. 8, 1932)

ABSTRACTED BY J. K. HOSKINS

This article is a summary of information on the construction and operation of the Bradford, England, Sewage Disposal Works, gleaned from a recently revised booklet issued by the city.

The sewage from 287,400 population, amounting to $23^{3}/_{4}$ m. g. d. is treated in the disposal plant. The large wool scouring industries of Bradford contribute wool scouring wastes all of which are now added to the domestic sewage and treated at the plant. Previously lime was used as a precipitant but now sulphuric acid manufactured at the works is employed. The policy of requiring separate treatment of the wastes by the industry proved to be impracticable and was abandoned. The crude sewage contains 890 p. p. m. of grease, the proportion in the daytime being much higher.

The acid is added to the crude sewage to crack the soaps and to pre-

cipitate dissolved and suspended organic matters and wool waxes. Acid sewage is difficult to filter, therefore the amount of acid used is reduced to the minimum and only at times when the excess of wool wastes require it. Best results are obtained with a pH value of about 6 for the tank effluent. The settled effluent is treated on 53 acres of filters, 6 feet deep, at the rate of 35 gallons per cubic yard daily. Hard, Yorkshire coal is the filtering medium, the cheapest material available, and has proved entirely satisfactory. Such filters are potential sources of fuel in times of emergency and have actually so served. The calorific value is not affected by long years of service in the beds.

All of the sludge from detritus and precipitation tanks is pressed for grease extraction after heating in large vats by steam coils. It has been found that the inclusion of the grit is a valuable component of the sludge-pressing compound as well as is the paper and fibrous floating matter, hence preliminary screens are not used. The liquid grease and water is discharged through cotton cloths of the filter presses. The press-cake is stored and dried for a year in the open and is of value as a fertilizer.

Study of the Waste Water of Cider Factories and Apple Distilleries—Their Purification before Discharge into Streams

BY C. WARCOLLIEN

Chimie et industrie, **26**, 30 (1931); Abstr. No. 236, *British Summary of Current Literature, Water Pollution Research* (Feb., 1932)

A distillery treating 100 tons of apples daily discharges 200 cu. meters of washing water and 150 cm. of vinasse, the residual liquor from distillation. Irrigation is most practical and economical if permeable ground is available. A treatment process used in factories consists in precipitating the vinasse with milk of lime to give an alkalinity of 2 gm. CaO per liter. The supernatant liquor is drawn off and aerated. The treated liquid can be discharged into a stream if the dilution provided is at least 200 times. Lime treatment precipitates not over 50 per cent of the nitrogenous substances, or 30–40 per cent of the carbonaceous, but removes nearly all the tannin. The vinasse cannot be neutralized with lime carbonate, but well-burned lime with a high CaO content is necessary. Treatment with ferric salts and lime was no better than with lime alone. It was observed that when a treated vinasse was discharged at the rate of 250 cm. per day with a dilution of 1:250, the minimum dissolved oxygen was 10 mg. or 7 per liter, sufficient for most fish, including trout.